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Arizona State Dept. of Health Services, Phoenix

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Ninth North American
Motor Vehicle Emissions Control Conference

Scottsdale, Arizona
May 4-7, 1982

SPONSORS

State and Territorial Air Pollution Program Administrators
U.S. Environmental Protection Agency

HOST

Arizona Department of Health Services
Bureau of Vehicular Emissions Inspection

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This report includes the various issues discussed at the North American Motor Vehicle Emissions Control Conference held in Scottsdale, Arizona on May 4-7, 1982.

A few of the issues presented within this report include: The Clean Air Act Amendments, air quality planning, monitoring and modeling, alternate fuels, exhaust emission control for light-duty and heavy-duty vehicles, diesel engines and inspection and maintenance programs.

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FRIDAY, MAY 7

MORNING

8:30 SESSION V. INSPECTION AND MAINTENANCE PROGRAM/ IMPLEMENTATION

Moderator - Ron Householder
Oregon Department of Environmental Quality

A. Political/Public Relations Issues Involved
Pete Hildebrandt, Washington State Department of Ecology

B. I/M Effectiveness/Cost Effectiveness
Start-Up Problems, Training, Enforcement

1. Centralized
John Walluch, California Bureau of Automotive Repair

2. DeCentralized
James McGuirk, New York Department of Motor Vehicles

3. Colorado's I/M Data Handling System
Rick Barrett, Colorado Department of Health

4. Ambient Reductions
Kay Jones, Roy Weston, Inc.

C. Feasibility of On-Board/Off-Board Diagnostic Equipment
Robert VanCura and Joe Calhoun
General Motors Corporation

D. Viewpoints - Aftermarket Industries
Benjamin R. Jackson, P.E.
Specialty Equipment Manufacturing Association

12:00 ADJOURNMENT

* * *

STAPPA CHAIRMAN .... Daniel J. Goodwin, *Illinois EPA*
CONFERENCE CHAIRMAN .... Fred Iacobelli, *Arizona DHS*
PROGRAM COMMITTEE .... James D. Boyd, Chairman, *California ARB*
.... Helen Petrauskas, *Ford Motor Co.*
.... Ron Householder, *Oregon DEQ*
.... Maurice Thomas, *Colorado State University*
.... Ron Lancaster, *Systems Control, Inc.*
.... John Pattison, *University of Cincinnati*
ARRANGEMENTS .... LaNaeh Petersen, Chairman, *Hamilton Test Systems*
.... Bill Watson, *Arizona DHS*

Ninth Annual North American

Motor Vehicle Emissions Control Conference

May 4 - 7, 1982

SPONSORS
State and Territorial
Air Pollution Program Administrators
(STAPPA)
U.S. Environmental Protection Agency

HOST
Arizona Department of Health Services
Bureau of Vehicular Emissions Inspection

Ramada Valley Ho Resort — Scottsdale, Arizona

TUESDAY, May 4

EVENING

7:00 REGISTRATION, GET ACQUAINTED MIXER

WEDNESDAY, MAY 5

MORNING

8:00 REGISTRATION

9:00 CONFERENCE ORIENTATION

9:15 WELCOMING ADDRESS
James E. Sarn, M.D., M.P.H., Director
Arizona Department of Health Services

10:00 SESSION I. CLEAN AIR ACT AMENDMENTS - Discussion Panel
Moderator - *Bill Becker, Executive Secretary, STAPPA*
Panel - *Richard Wilson, Environmental Protection Agency*
David Hawkins, Natural Resources Defense Council
Mary Nichols, Air Resources Board
Helen Petrauskas, Ford Motor Company

AFTER NOON

12:30 LUNCHEON AND GUEST SPEAKER
Mary Nichols, Chairperson, California Air Resources Board

2:00 SESSION II. PLANNING FOR CLEAN AIR
Moderator - *Fred Iacobelli, Arizona Department of Health Services*

A. Current Air Quality and Trends in Various Areas
John Elston, New Jersey Department of Environmental Protection

B. Air Quality Planning - SIP Process, Problems
Jo Anne Aplet, South Coast Air Quality Management District
Fred Sanborn, Michigan Department of Transportation

C. Air Quality Monitoring/Modeling
  1. Adequacy of Mobile II, EPA Update
  Phil Lorang, U.S. Environmental Protection Agency
  2. SAI Air Modeling
  James M. Lents, Colorado Department of Health

D. Vapor Recovery - Effectiveness and Cost Effectiveness (Marketing, Usage)
Bob Bradt, HIRT Combustion Engineers

E. Mass Transit and Car Pools
Jack Hidinger, U.S. Environmental Protection Agency

6:15 FIRST BUS LEAVES FOR RAWHIDE

7:00 WESTERN COOKOUT AT RAWHIDE, North Scottsdale Road

THURSDAY, MAY 6

MORNING

8:30 SESSION III. CURRENT AND NEW CONTROL TECHNOLOGY—PASSENGER CARS
Moderator - *Helen Petrauskas, Ford Motor Company*

A. Projected Controls - Vehicle Manufacturers Look Into The Future
Harry Weaver, Motor Vehicle Manufacturers Association

B. Comparison of Effectiveness of Vehicle Emission Control Systems
Charles Pratt, Environmental Protection Agency

C. Effect of Tampering/Misfueling
Richard Kozlowski, U.S. Environmental Protection Agency

D. Significance of Engine Warm-Up Time on CO Emissions
Thomas Moyer and Michael E. Hoyles
Alaska Department of Environmental Conservation

E. Impact of Diesels
Jerry Gallagher, Colorado Department of Health

AFTER NOON

12:30 LUNCHEON AND GUEST SPEAKER
Sonia F. Crow, Regional Administrator
U.S. Environmental Protection Agency, Region IX

2:00 SESSION IV. CURRENT AND NEW CONTROL TECHNOLOGY—OTHER SOURCES
Moderator - *John Pattison, University of Cincinnati*

A. Heavy-Duty Vehicle and Off-Road Equipment Emissions Control
John McNally, Caterpillar Tractor Company

B. Diesel-Powered Vehicle Emissions Control
Bill Ansert, Volkswagen of America

C. Motorcycle Emissions Control
Roger Hagie, Kawasaki Motors Corp., U.S.A.

D. Alternate Fuels
  1. Alcohols and Other Oxygenates
  John Pattison, University of Cincinnati
  2. The California Programs
  Bob Cross, California Air Resources Board

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HOSTS:

GET ACQUAINTED MIXER .... Systems Control, Inc.
COOKOUT ADJUSTMENT .... Hamilton Test System, Inc.
COFFEE BREAKS .... Champion Spark Plug Company
Rang's Automotive and Truck Equipment, Inc.

NINTH NORTH AMERICAN
MOTOR VEHICLE EMISSIONS CONTROL CONFERENCE
(MVECC-IX)

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REGISTRATION LIST 383

PRESENTATION OF MICHAEL P. WALSH BEFORE NINTH ANNUAL MOTOR VEHICLE EMISSION CONTROL CONFERENCE

INTRODUCTION:

Good morning! It is always a pleasure to be in Arizona and to see so many familiar faces of friends. Unfortunatly, it is not so pleasant to be discussing the Amendments to the Clean Air Act, because the debate is still dragging on, months after it should have been completed. The Clean Air Act needs revision. As recently noted by Senator Gary Hart, Chairman National Commission On Air Quality, "Where the Act has created an unnecessarily complex regulatory maze, it must be streamlined and simplified". However the effort on the part of some to throw out the baby with the bathwater, to steal a cliche, has significantly delayed reasonable action. In my presentation today, I would like to briefly describe the motor vehicle related changes contained in HR 5252, THE DINGELL-LUKEN-BROYHILL bill, and then, by way of illustration, to focus on the problems associated with two of those changes. H.R.5252 includes the following changes related to motor vehicles:

1. REQUIRES 48MONTH LEAD TIME FOR ANY TIGHTENING OF HEAVY TRUCK REGULATIONS; 36 MONTHS FOR CARS
2. BEFORE SETTING ANY NEW STANDARD THE ADMINISTRATOR MUST DETERMINE THAT TECHNOLOGY HAS BEEN "DEMONSTRATED" TO BE AVAILABLE TO MEET STANDARD
3. STRIKES REQUIREMENT FOR TRUCK STANDARDS OF EQUAL STRINGENCY WITH AUTO STANDARDS
4. REQUIRES NAS STUDY BEFORE ADOPTION OF ANY PARTICULATE STANDARD FOR TRUCKS
5. REQUIRES NOTICE AND OPPORTUNITY FOR COMMENT BEFORE ADMINISTRATOR CAN DETERMINE THAT DEVICE CAUSES UNREASONABLE RISK TO PUBLIC HEALTH, WELFARE OR SAFETY
6. RELAX AUTO CO STANDARD FROM 3.4 TO 7.0
7. RELAX AUTO NOX STANDARD FROM 1.0 TO 2.0
8. AUTHORIZE INNOVATIVE WAIVERS FOR UP TO 200,000 VEHICLES PER MANUFACTURER PER YEAR TO ANY LEVEL
9. REDUCE THE USEFUL LIFE FOR WHICH TRUCK STANDARDS

MUST BE MET TO ONE-HALF ACTUAL LIFE

10. RELAX HIGH ALTITUDE STANDARDS

11. REDUCE TESTING REQUIREMENT PRIOR TO VEHICLE PRODUCTION

12. PROHIBIT EPA FROM TIGHTENING THE ASSEMBLY LINE TEST REQUIREMENTS

13. MODIFY RECALL REQUIREMENT SO THAT COMPLIANCE IS DETERMINED BY THE AVERAGE RATHER THAN ALL VEHICLES

14. REQUIRE VEHICLES TO BE ADJUSTED TO MANUFACTURERS SPECIFICATIONS PRIOR TO RECALL TESTING

15. NO LONGER REQUIRE VEHICLES WHICH FAIL THE RECALL TEST PROGRAM TO BE FIXED

16. REDUCE WARRANTY FROM 5YRS, 50,000 MILES TO 2YRS, 24,000 MILES

17. REDUCE PARTS COVERED BY WARRANTY

18. REDUCE SCOPE OF TAMPERING PROHIBITION

19. ELIMINATE MANDATORY I/M REQUIREMENT

I THE AUTO NOX STANDARD

Doubling the existing automobile NOx standard, just one year after it has finally been achieved following more than a decade of sometimes intense effort,would be a grave step backward in our nation's efforts to protect public health and welfare.Over the next twenty years, we will need to control many sources of nitrogen oxides to levels much more stringent than they currently achieve, and even then it is very unlikely that we will be able to restrain projected nationwide growth of this pollutant. These additional controls will be needed for both stationery and mobile sources (especially heavy duty trucks and buses). A relaxation in existing standards for any source which is currently being controlled in a cost-effective manner and for which the research and capital investment has already been made would either allow ambient air guality levels to be worse than they would otherwise be or require additional control of sources which have already been found to be the most difficult and expensive to restrict. Since automobiles are so pervasive, the potential impact of a relaxation in its emission rates is greater than would result from almost any other single source.

Total nationwide nitrogen oxides emissions have nearly tripled in the past 25 years, with mobile sources responsible for a significant portion of this growth. As EPA has testified further significant growth in total nationwide NOx is projected even with tight auto controls. Increases will be even worse if we roll back the 1.0 gram per mile auto standard; doubling this standard after only one year of control seems to fly in the face of all the concerns which we have about NOx emissions— and there are several.

First, annual average ambient nitrogen dioxide (NO2) levels are directly responsible for adverse health effects when the National Ambient Air Quality Standard established by EPA is exceeded. Secondly, it is increasingly clear that exposure to NO2 peaks for even short periods of time can result in adverse health impacts. Further, NOx is a precursor to photochemical smog and ozone, the most widespread air pollution problem in the country.Finally, NOx has recently been identified as contributing to the emerging acid rain problem.

While only a few areas of the country exceed the annual average NO2 air quality standard at present, it is the only one of the major motor vehicle pollutants which clearly deteriorated during the past decade and depending on auto and truck standards as well as long term growth it could show further, significant deterioration before the end of the century. For example, in recent testimony before the U.S. House of Representatives, Subcommittee on Health and the Environment, the Manager of the Illinois State Environmental Protection Agency, noted that failure to tighten truck emission standards coupled with a relaxation of the auto standard "could make it very difficult to ever attain and maintain the ambient standard for nitrogen dioxide in Chicago. With the current tailpipe standards, the ambient standard violations are expected to fade away in the next few years."Analyses summarized in statements submitted to the Subcommittee on Health and the Environment by Governor Rockefeller, Chairman of the National Governors Association Committee on Energy and Environment, and by the President and Past-President, respectively, State and Territorial Air Pollution Program Administrators concluded that relaxation of the new light duty vehicle emission standards for nitrogen oxides would aggravate existing nonattainment problems and, in numerous urban areas across the country, lead to non attainment problems which would otherwise not exist. More specifically, the analyses conclude that:

* Average total loadings of NOx will increase above the levels otherwise projected to occur by 13-16% in 1987 and by 28-39% in 2000.

* 8 new areas could become non-attainment for NO2 after 1982

* 11-14 areas could face the need to apply additional controls on stationary sources in order to reach or maintain NO2 attainment

EPA's own analyses indicate that several other cities which currently attain the air quality standard would have similiar problems.

While the current air quality standard is based on annual average NO2 levels, a growing consensus within the scientific community believes that short term NO2 exposures may be an even greater cause of health concern.This concern was reenforced by a study released by EPA in March of last year in which adverse health effects were noted in school children in Akron,Ohio, who were exposed to levels of NO2 and SO2 belowtheir respective air quality standards. While the short term NO2 level which causes adverse impacts has not yet been decided by EPA, it is inappropriate to roll back the standard which may have the largest impact on ambient levels until EPA determines the safe level.

An additional concern with regard to nitrogen oxide emissions is the impact on ozone air quality. While this is a complicated subject and not fully understood at present, and while some have argued that increased NO2 levels can lead to lower ozone levels under some circumstances, the scientific consensus is that NOx control will be necessary if we are to adequatly address the widespread ozone problem. For example, a panel of national experts convened by the National Commission On Air Quality recently stated:

> "A majority of the panel agreed that NOx control as well as HC control is needed. NOx control can reduce ozone locally in multiple day episodes and downwind in transport situations and it can reduce other nitrogen bearing pollutants."

The National Academy of Sciences made the same point in its 1977 study of nitrogen oxides.

The National Academy of Sciences also released a recent report which discusses the subject of acid precipitation and among other things the role of

NOx emissions. While pointing out(as noted above) that"there has been an increase in emission of nitrogen oxides for the past few decades" and that "in the absence of control technology for nitrogen oxides, their emissions will exceed emissions of sulfur oxides by the turn of the century," the Academy concludes that "control of emissions of sulfur and nitrogen oxides from fossil fuels is necessary to halt the acidification of sensitive aquatic ecosystems" In the face of (1) an annual average NO2 air quality picture which probably will worsen over the next two decades even with tight automobile NOx controls, (2) a growing consensus that short term NO2 levels which tend to be dominated by mobile sources may be even more of a health concern than annual average exposures, (3) the negative role of NOx in contributing to the widespread and pervasive ozone problem and(4) the emerging concern with acid deposition and the growing awareness of the role which NOx plays in its formation, the only possible conclusion seems to be that any relaxation, much less a doubling, of the auto NOx standard has a high probability of further jeopardizing public health and welfare.

I think it is worth asking what will balance the increased public health threats associated with these relaxations? How much will it help the auto industry and the economy? Some have argued that the current lack of sales within the auto industry is adequate reason to relax standards, that doubling standards will allow prices to be reduced and increase sales sufficiently to get the industry back on its feet. To its credit, the auto industry is not among those making this argument. In fact, Dr. Betsy Anker-Johnson of General Motors was quick to point out in her testimony before a House subcommittee late last year, "General Motors has never contended...that emission rules should be relaxed to help Detroit out of its present economic difficulties."It is easy to see why this is the case if we return to the EPA estimates; doubling the CO and NOx standards will only reduce car prices about $40 to $90 per car, compared to an average new car price approaching $10,000. Further, removing the advanced hardware, may cost more in terms of excess fuel consumption than will be saved leading EPA to note in its recent submission to the subcommittee that "even small fuel economy improvements that might well result from the more sophisticated fuel metering systems used under the more stringent standards could easily overwhelm the differences in the costs of the emission control systems, even at current fuel prices." It seems clear that the problems of the auto industry are most related to the general state of the economy,i.e., high interest rates, high inflation eating up disposable income,etc. and that the industry fortunes will only improve when the general economic climate improves. A Merrill, Lynch, Pierce, Fenner and Smith vice-president recently noted in Business Week that even a $650 to $700 price cut "won't turn the industry around." He continued, "There has to be a stronger economy."

Finally, in recent months, several national polls have shown that there is broad public support for retaining if not tightening the auto emission standards. If the intent of relaxing auto standards, therefore, is to reduce the price of new cars , the public has spoken loudly and clearly that it wants no such reduction at the expense of clean air. the issue being debated should not be whether to relax auto standards but rather on what schedule and to what degree should we impose similiar standards on trucks,buses and other stationery sources to minimize the health and welfare problems which are clearly on the horizon, and in some cases already with us

While much of the Clean Air Act debate is over standards, compliance with standards when cars are in the hands of consumers is at least as important if not more so. Compliance with standards is ultimately dependent upon vehicles being maintained and adjusted properly. Inspection and Maintenance (I/M) programs are the best way to bring this about. Inspection and maintenance is intended to identify cars which need remedial maintenance or adjustment and require repair of those cars. It encourages vehicle owners to keep their cars in a good state of repair, the service industry to do the maintenance properly and the manufacturer to make vehicles ore serviceable and durable.

Inspection and maintenance is not a hypothetical idea but as you know a current reality not only here in Arizona but in New Jersey, Portland, Oregon, Rhode Island, Seattle, Atlanta, Denver, New York and Virginia. Contracts have been awarded to put programs in place in Albuquerque and Connecticut. Barring changes to the Clean Air Act, I am confident that it will also be implemented in many other polluted areas of the country. Why is this important? Because - as has now been demonstrated in Portland and New Jersey and Arizona - I/M reduces CO and HC emissions from cars dramatically, at reasonable cost and with broad public support. As recently noted by the Mayor of Phoenix, Arizona, "the I/M program is among the most effective and least disruptive of the measures available to control air pollution. Attaining the Federal standards through this method does not significantly affect our desired lifestyle...There may be a variety of ways to control automobile pollutants, but we have found the I/M program to be the most effective pollution control strategy in Phoenix."

THE FEDERAL ROLE

Since I/M has widespread public support and has been demonstrated to cost-effectively remove significant amounts of CO and HC, some have suggested that it should no longer be required by the Federal government. This is of course the basic thrust of H.R.5252. The reasoning presumably is that it will be implemented in those areas which have serious air pollution problems even if it is made optional because it is an attractive air pollution control program. Unfortunatly, this has not been the experience in the past. For example, prior to the adoption of the Clean Air Act Amendments of 1977, which specifically mandated I/M for areas with the most serious problems and imposed growth and funding limitations on areas which did not proceed, only New Jersey, Oregon and Arizona adopted adequate programs. Since adoption of the 1977 Amendments, Rhode Island, New York, Virginia, Colorado, Washington and Georgia have been added to the list of areas actually testing cars. Further, Connecticut and New Mexico have signed contracts which will result in programs in the near future. Virtually all other areas which need the program have made significant progress since 1977 and there is good reason to expect that the maximum number of programs will be implemented if the Federal government just maintains its current approach. An EPA analysis of the impact which I/M could have had by now if were mandated by the 1970 law in the same way it has been in 1977 shows that hydrocarbon and carbon monoxide emissions from cars would have been 27 and 34% lower, respectively. A rollback in I/M requirements now will certainly increase the risk that we will be in the position five years from now of expressing regret over the public health benefits foregone by that decision.

In addition to the increased likelihood that we will have fewer I/M programs and the proven benefits associated with them there are several other reasons why the current requirement should be retained:

1) One of the pollutants which an I/M program addresses, hydrocarbons, can be transported large distances. Therefore, pollution generated in one state can cause or exacerbate air pollution problems in neighboring states. Only by requiring reasonable measures which are demonstrated to be effective and cost effective to be implemented in all non-attainment areas, can we equitably deal with this dilemna. Just as Reasonably Available Control Technology (RACT) is required on stationary emission sources, I/M is an appropriate "minimum" requirement in those areas with severe motor vehicle related problems.

2) Many of the urbanized areas which most need I/M programs involve two or more states. To adequately and equitably address the problem in these areas, uniform minimum requirements are needed. Unilateral action is not satisfactory. Of the 29 states (including the District of Columbia) which currently require I/M, almost half have at least one interstate area involved. These states are:

a) Connecticut (New York City)
b) Delaware (Wilmington)
c) District of Columbia (Washington, D.C.)
d) Illinois (Chicago, St. Louis)
e) Indiana (Chicago, Louisville)
f) Kentucky (Louisville, Cincinnati)
g) Maryland (Washington, D.C.)
h) Missouri (St. Louis)
i) New Jersey (New York City, Philadelphia)
j) New York (New York City)
k) Ohio (Cincinnati)
l) Pennsylvania (Philadelphia)
m) Virginia (Washington, D.C.)

3) As noted above, most states have appropriately taken action in response to the current Clean Air Act requirements. To undercut these efforts by removing any requirement for those few who have dragged their feet will convey exactly the wrong message.

In summary, in considering adjustments and mid-course corrections to the Clean Air Act, the I/M provisions seem to reflect an area which is working, achieving its intended objective. If anything, the data base upon which the program is based is better than that which existed in 1977 - we should continue to preserve our multiyear investment in motor vehicle pollution control.

CONCLUSIONS

Through these two examples, the auto NOx standard and I/M, I hope I have illustrated how the Dingell-Luken-Broyhill bill goes too far. Remember that these are but two of nineteen changes in the motor vehicle program alone which are contained in the bill. Not a single one of these changes reflects a tightening of the requirements. By cutting so deeply into elements of the Act which are working and have been demonstrated to be effective, the authors are not only gambling unnecessarily with public health, they have delayed appropriate and reasonable changes to the Act which could have and should have occurred by now and have increased the risk that again this year no bill will be adopted.

PRESENTATION OF
MARY D. NICHOLS, CHAIRPERSON, AIR RESOURCES BOARD,
TO THE STAPPA MOTOR VEHICLE EMISSION CONTROL
CONFERENCE, CLEAN AIR ACT PANEL

SCOTTSDALE, ARIZONA

MAY 5, 1982

Dingell/Luken bill backed by Reagan Administration is not alright with California. The California waiver is a reprieve, not a pardon for the California program.

Control technology to meet current standards is available. The investment has paid off handsomely and the cost, compared to the proposed rollback, is 1-2% of selling price of average car.

There are no clear benefits. Relaxation will do nothing to end the recession in the auto industry. It will not affect consumer buying habits, sticker shock or foreign competition. I doubt that it would put one layed off auto worker back on the job.

It will make the air dirtier. The amount of damage will vary but the directional effect is clear - delays in attaining health-based ambient standards in more than 30 states.

Let us avoid the mistake of getting lost in a numbers game. We are talking about public health. Relaxation will change emission control systems and will tend to increase all automotive pollutants. People in urban areas throughout the country are breathing air containing ozone, other oxidants, lead, carbon monoxide, fine particles, nitrogen oxides and a host of other chemicals. These people are the real losers if standards are relaxed. They are the reason this country made its commitment to clean air and they are the reason that commitment cannot be abandoned.

For those who believe as I do let me recall for you the context of the debate over vehicle standards. Administratively, EPA is in high gear. More than 50 separate actions have been taken since January 1981 to relax the federal vehicle program. Dozens of others have been taken which affect stationary sources. A few of these are reasonable, but collectively they constitute a major retrenchment by EPA.

We must also remember the political context. The politics of the debate are such that the vehicle standards relaxation is an inseparable piece of a package deal. The package is a major environmental policy reversal - the most significant change in direction since Earth Day in 1970.

The Dingell-Luken-Reagan coalition is offering no compromise. By the rules of debate they have dictated if the vehicle standards are relaxed so will the rest of the Clean Air Act. There will be no action on acid rain, toxic chemicals or SIP reform. It is a package that must be rejected.

THE CLEAN AIR ACT

SHAPING THE ENVIRONMENTAL POLICY FOR THE 1980's

HELEN O. PETRAUSKAS
DIRECTOR

AUTOMOTIVE EMISSIONS AND FUEL ECONOMY OFFICE
FORD MOTOR COMPANY

PRESENTED TO:
THE NINTH NORTH AMERICAN MOTOR VEHICLE EMISSION CONTROL CONFERENCE
STATE AND TERRITORIAL AIR POLLUTION CONTROL ADMINISTRATORS
SCOTTSDALE, ARIZONA

May 5, 1982

Perhaps it is stating the obvious to say that environmental policy for the 1980's will be predicated on what has come before it. The 1960's were a period of developing awareness and establishing goals. This was a period of education for the private sector. In general, industry exhibited little of what we now call "environmental conscience." There was meager awareness and appreciation of the importance of making pollution control a part of the day-to-day business process. Pollution control cost money, did not sell products, and showed up as an identifiable negative on the bottom line. Not only have these attitudes changed in our industry, it's hard to remember how they were ever justified.

The '70s were a period of advocacy and confrontation. Issues were aired in an atmosphere of conflict. Suspicion led to overly inflexible approaches to addressing problems which in turn led to even greater polarization of positions. For those in the auto industry, the Congressional debates of the '70s were a frustrating and discouraging experience. Appearance had more importance than substance. There was much talking and little listening even though by that time, we had acknowledged the need for controls and were questioning only levels and timetables. It is perhaps in spite of all of the participants in the debate that this decade nonetheless produced significant environmental progress.

That is not to say that we ought continue this approach for the '80s. There is good reason to believe that the time has come to take a more cooperative, flexible and reasoned approach and, as you might expect, I've come equipped with some ideas on how we might proceed. Also, as you might expect, my themes come from the recent Clean Air Act debate.

Unique State Mobile Source Strategies

We are convinced that the states, all of you, are the key element to this approach. Let me give you some examples. In the 1980's, we expect to see a move in the direction of unique fleets for various areas of the country that are perceived as having unique air quality problems. In 1970, the auto industry vehemently opposed multiple sets of standards saying that anything but a nationwide car would be unworkable. We were wrong. California has had a program since the late '60s. The program works well and makes a great deal of sense. There is little point in imposing costs and burdens on the entire nation to achieve controls which are tailored for California's needs. Similarly, today we produce a unique fleet of vehicles for high altitude areas because we have learned that emission control systems function differently at 6,000 feet than they do at sea level. Again, given the fact that altitude sales represent some 3% of nationwide sales, it cannot be in the public interest to design all cars to be capable of meeting emission standards under the conditions encountered in Denver or Albuquerque. Of course, there is a limit to our ability to produce and market unique fleets. One reason the California and altitude programs have worked well is because they "piggyback" to such a large extent on the federal program. For example, we and California have put a lot of effort into minimizing procedural and paperwork differences between the California and federal programs. Another reason is that it is in our selfish interest to make these unique programs work well -- the alternative of designing a universal car that automatically and simultaneously meets the environmental needs of Denver and Los Angeles and the rest of the nation will please no one.

Looking at these concepts in terms of our recommended Clean Air Act changes, we are committed to a continuation of the California program of unique more stringent standards and associated certification, assembly line test and field surveillance procedures. We are likewise committed to continuing to provide a fleet of vehicles with emission control systems tailored to meet high altitude air quality needs. For the rest of the nation, however, vehicle standards should be no more stringent than those needed to meet the ambient air quality standards. While there have been in the past, and probably will continue to be, honest differences of opinion as to California and high altitude air quality needs or appropriate levels outside these two areas, we fail to see how the overall national interest is served by imposing more stringent than necessary controls in all areas.

Inspection Maintenance

It's clear to us from the debate that I/M is here to stay. Regardless of the type of I/M program that may ultimately be put in place in the '80s, whether it is today's program or a substantially different one, cooperation between manufacturers, state officials, and EPA is essential. We want to keep our customers happy and you will need acceptance of the program on the part of your citizens.

SIPs

Also here to stay are SIPs and the tie in between stationary and mobile source control has been given particular emphasis. I believe our industry has been somewhat remiss in not working more closely with the states in the development of the portions of the state implementation plans that relate to mobile sources. We have done and must do even more work in assessing the emissions from vehicles in the hands of consumers. We have done and must do more research with respect to the relationship between vehicle emissions and air quality. Through our trade association, we have been meeting with state air pollution control officials to exchange data and information on air quality modeling. Frankly, the effort was initiated because of issues arising out of the current Clean Air Act debate. As you might imagine, the atmosphere created by that debate is not one most conducive to a reasonable, cooperative exchange of views and information. We see this effort as an ongoing one and hope that long after the heat of the congressional debate is behind us we will continue to see the benefits of this effort.

Enforcement

An undercurrent of the entire air quality data debate has been the issue of enforcement. I don't need to point out to any of you the recent criticism, at least in some quarters, regarding EPA's effort to negotiate more and go to court less as a way of improving the effectiveness of environmental enforcement programs. The thrust of this criticism seems to be that the best measure, and according to some the only measure, of effective compliance is the number of cases referred to the Justice Department. I thought you might be interested in knowing that on the mobile source side the negotiating approach has been in place for almost a decade. Here are some facts: Since 1977, for example, EPA has probably conducted over 400 mobile source surveillance programs, some of these with regard to cars as they come off the end of the assembly line, while others involved older cars in the hands of consumers. During the same period, thousands of routine compliance reports were filed by manufacturers. That's a lot of compliance programs, given the relatively small number of manufacturers.

During this same period, there have been approximately 100 recalls, some involving very few cars (e.g. 30), some involving larger numbers.

What is significant is that the majority of these recalls -- I would estimate perhaps 90% -- did not involve a formal complaint of non-compliance by EPA but rather represented either wholly voluntary action by manufacturers or some level of negotiation between the manufacturer and EPA. As best I can tell, only one of these recalls involved enforcement by the courts. What is even more significant is that the vast majority of vehicles have been found to comply with standards when the vehicles are properly used and maintained.

This pattern of voluntary compliance has not varied significantly from administration to administration and has simply been a program that has worked very well. I mention this because it is our sense that much of the opposition of state environmental officials to changes in new car standards is a worry that a change in the standards or in enforcement or both will force states into additional control of stationary sources or more burdensome transportation controls. In our view, the air quality data demonstrate that CO and NOx standard changes can be accommodated within existing NAAQS; and we foresee no air quality deterioration as a result of continuing the enforcement approach taken in the past. In any case, as a safeguard, we are also supporting provisions which would direct EPA to make the standards more (but not less) stringent in future years if it is necessary to do so to meet ambient standards.

One change we would like to see with respect to mobile source enforcement - particularly as it relates to testing vehicles in the hands of customers - is a structuring of the program to make it multi-purpose. Given the substantial cost of acquiring and testing in-use vehicles, it would be very worthwhile to obtain test results not only for "pass-fail" determinations but also to obtain information which could then be integrated into improving the design of future vehicles.

Technology Forcing

Finally, no discussion of mobile source Clean Air Act themes is complete without mentioning the "keep their feet to the fire" approach. One of the characteristics of this year's clean air debate is the view by some that Congress cannot trust EPA with the responsibility to determine dates as to when certain requirements need be met, specific levels, or the specific approach to be used to reach the specific level by the specific date. What is surprising is the widely held notion that somehow this distrust of the regulator is unique to this Congressional debate and to this Administration. Certainly in the mobile source area that is not the case. There's a long history of Congress making all the nitty-gritty decisions. Congress did it to Mr. Rucklehaus in 1970, Congress did it to Mr. Train in 1974, Congress did it to Mr. Costle in 1977 and some in Congress would do it to Ms. Gorsuch in 1982.

The consequences of this kind of rigidity are profound. The establishment of specific dates and specific levels arbitarily in the statue -- without debate as to the alternate technologies, costs and other factors -- predetermines the choice of technology used, whether or not that technology in fact represents the best choice in light of competing concerns. Further the regulator lacks the flexibility to adjust for changed circumstances.

Most importantly perhaps, the focus on technology forcing precludes an adequate consideration of need. The typical rebuttal to the adverse impacts of technology-forcing is the assertion that "if we don't force development of the technology that can achieve the lowest levels, we will never know how much progress can be made". There's no easy answer to this concern but perhaps some combination of approaches is needed. Certainly, a review of requirements set earlier and a readjustment as the facts warrant would be of great help, particularly because it is the last few percentage points of reduction that have proved to be most costly. For this approach to work there must be a willingness to recognize that the requirements set earlier were not divinely inspired and represented not a measure of need or a measure of effectiveness, but simple technology forcing.

In closing, I would like to say that we have learned a lot in this Congress' clean air debate. I do believe much of the disagreement between industry and the states could have been avoided if we both had had a better understanding of the objectives and data of the other. For our part, we are committed to continuing the dialogue we've finally begun; and I'm certain that continued exchange of ideas will minimize our differences in the future.

35/400/D

Ninth Annual North American
Motor Vehicle Emissions Control Conference

PROBLEMS WITH THE SIP PROCESS IN SOUTHERN CALIFORNIA

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PROBLEMS WITH THE SIP PROCESS IN SOUTHERN CALIFORNIA

Everyone knows that Southern California has a major pollution problem. That it also has a planning process nearly as complicated as the pollution problem to be solved may not be as obvious.

PROCESS

There are three agencies with primary responsibility for developing the SIP in Southern California. They are:

- The South Coast Air Quality Management District, which is the local agency with final approval--responsible for developing industrial controls, for stationary source inventory, development and modeling.

- The Southern California Association of Governments, which does population forecasting and local government coordination and is responsible for the transportation control measures.

- The California Air Resources Board, which developed many of the mobile source and area source emission estimates, and which has taken lead responsibility for preparing the inventory in a gridded format for modeling.

The agencies have also worked closely with the California Department of Transportation (Caltrans), which has been responsible for modeling of transportation patterns. Based upon this information, the Southern California Association of Governments has developed emissions forecasts, based on the anticipated growth for the region.

PROBLEMS WITH 1979 PLAN

Together, these agencies produced the 1979 Nonattainment Plan for the South Coast Air Basin. The major deficiency they faced in developing the 1979 NAP was time.

- Not enough time for EPA to prepare guidelines.
- Not enough time to prepare a good inventory and model reductions.
- Not enough time to analyze the cost and effectiveness of tactics.
- Not enough time to develop institutional arrangements for long-term planning.
- Not enough time to develop a review process which provided adequate public understanding and support for implementing the program.

The 1977 Clean Air Act emphasized short-term implementation of industrial controls and long-term transportation planning, on the assumption that together these would be adequate for all areas of the country to demonstrate attainment of all federal standards. In our case, the assumption is clearly wrong.

Our problem has been compounded by the lack of adequate resources. Funding for developing the 1979 Nonattainment Plan was not received until after the Plan was completed. Federal guidelines for disbursing Sec. 175 money concentrated on implementation, not planning. The technical requirements for developing a plan clearly exceeded that which could be delivered within the time frame allowed by the Act--and we were already well into the process!

The result of inadequate time and resources was a plan that was delivered on schedule, but which was followed by a somewhat acrimonious review period and conflict between the various responsible agencies still not fully resolved. The 1979 Plan was only recently conditionally approved by EPA. Final approval is still hung up pending implementation of an inspection maintenance program in California.

NCAQ STUDY

The National Commission on Air Quality undertook a massive study of the 1979 planning process in the South Coast. After spending over a million dollars, far more than went into the original Plan, the National Commission concluded that the South Coast Plan was inadequate.

1982 REVISION

In response to the questions raised during the review period, our focus since 1979 has been on developing a comprehensive inventory. We believe it to be the best in the country. Modeling has been improved. We have developed gridded inventories and improved computer capability. We have contracted with Systems Applications, Inc. in San Rafael to perform some supplemental modeling studies which we will release concurrently with the Plan for public review.

The control measures in the Revision have already received very lengthy, painstaking review. Unfortunately, we have not been able to come up with significant new measures beyond those which were outlined in the 1979 Plan. Further analysis of these has revealed less emission reduction at higher cost.

We have encountered far more population and industrial growth in the region over the past five years than we had anticipated. We are also forecasting much greater growth through the year 2000 than what we predicted in 1979. The result: the distance we have to go to demonstrate attainment is far greater than what we previously thought.

For a while, we could benefit from the 1979 energy crisis, which temporarily resulted in reduced VMT and more use of public transit. However, the latest figures from the California Department of Transportation indicate that VMT is climbing again. The loss of federal subsidies is cutting back on funding for major transportation projects. As a result, we see more emissions and less benefit from our transportation controls than what we previously forecast.

We're also finding that as the planning becomes more complex and simplistic solutions elude us, we face public apathy and a sense of hopelessness. We need strong support from EPA to the goal of continued progress and away from simplistic admonitions to attain. The staffs of the participating agencies are determined to produce a feasible plan which sets the South Coast on a clear-cut path to cleaner air but with no firm attainment date. Whether EPA can accept this approach still remains to be seen.

SUMMARY

The above are process problems. Our underlying problem is that we are unable to demonstrate attainment of the ozone standard in the South Coast Air Basin by 1987 or any other date, given implementation of all the quantifiable measures currently available to us. To reach that goal will require major fuel changes for automobiles and industry. We can get at least part of the way there through such new technology as telecommunication, which may be able to reduce the rate of increase of travel. We can move towards clean air despite the pressures of population growth, public apathy, and lack of resources.

A HANDBOOK FOR EVALUATING THE AIR QUALITY AND ENERGY IMPACTS OF TRANSPORTATION SYSTEM MANAGEMENT STRATEGIES

MICHIGAN DEPARTMENT OF TRANSPORTATION
BUREAU OF TRANSPORTATION PLANNING
MAY 1982

Presented by Fred Sanborn

to

Ninth Annual North American
Motor Vehicle Emissions Control Conference

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The initial draft of this handbook was prepared by the staff of the Michigan Department of Transportation (MDOT) using information compiled by Systems Control Technology, Inc. (SCT), Crain and Associates and Pacific Environmental Services, under contract to the Environmental Protection Agency. Subsequent revisions were prepared by MDOT, Transportation Planning Services Division, Bureau of Transportation Planning.

The fuel consumption model used as part of the computer modeling effort was designed by SCT and implemented by MDOT. All other computer modeling was performed by Glenn Robinson with technical assistance from Bob Hull, Jim Eisfelder, and advice from SCT. The technical edit was done by Lisa Averill.

This is a partial copy of the Handbook which was prepared by the Energy and Air Quality Unit, Transportation Planning Services Division, Michigan Department of Transportation. The purpose of the Handbook is to assist local planners in evaluating the air quality and fuel consumption impacts that result from implementing Transportation System Management measures. The final document will be available within the next few weeks.

If you have any questions please feel free to contact Glenn Robinson or Lisa Averill at 517-373-2226.

CHAPTER I

INTRODUCTION

This handbook is a tool that state and urban area planners, engineers, and local officials can use when evaluating and selecting transportation projects. This handbook provides non-computer methods for the determination of air quality and energy impacts of the transportation control measures listed in Section 108 of the Clean Air Act. These non-computer calculation methods will produce approximate emission reductions and fuel savings which can be used to evaluate the relative benefits of each measure. This handbook provides Michigan planners with a tool for compliance with the Clean Air Act requirements for the development of urban-area transportation control plans. Such plans will, as a result of the use of this handbook, contain measures which complement one another and contribute to the combined goals of improved air quality, reduced fuel consumption, and an efficient transportation system.

Chapter two presents background information about the Clean Air Act and its relationship to transportation planning. It discusses transportation systems management and transportation control planning, provides guidance about the contents and form of a transportation control plan, and identifies logical links to energy conservation planning.

Chapter three identifies the data needed to use the handbook and explains the analytical approach used in the handbook. It discusses each of the transportation control measures, presenting a literature review and methods for calculating the air quality and energy benefits of each measure. Chapter three also discusses the order of analysis and research methods to be used with this handbook.

The final chapter contains a brief review and analysis of transportation control measures which are infeasible for use in Michigan. Planning agencies need not include these measures in their transportation control plans.

CHAPTER II

BACKGROUND

2.1 Clean Air Act Requirements

The Clean Air Act, as amended in 1977, requires states to meet federal ambient air quality standards. The Environmental Protection Agency (EPA) enforces the Act, and has the authority to impose penalties if states fail to comply. The Clean Air Act (CAA) requires the control of emissions from both stationary and motor vehicle sources of pollution. States have adopted administrative rules requiring emission controls on industrial sources of pollution. Auto manufacturers have complied with the law by designing cleaner and more efficient engines, and by equipping vehicles with devices that remove pollutants from auto tailpipe exhaust. Other CAA requirements have prompted transportation agencies to implement highway projects that decrease vehicle emissions, since motor vehicles are responsible for approximately half of the hydrocarbons and 90 percent of the carbon monoxide emitted in urban areas.

2.2 State Implementation Plans

In 1979, each state was required to submit a revised State Implementation Plan (SIP) containing project plans, rules, and schedules indicating how the individual state would implement the CAA and meet air quality standards for ozone, carbon monoxide, and in some cases nitrogen oxides. In Michigan, the SIP lists five urban areas as non-attainment areas for the pollutants ozone and/or carbon monoxide. These areas are Detroit, Flint, Grand Rapids, Lansing, and Niles-South Bend.

2.3 Delegation of Planning Responsibilities

Under the 1977 CAA, responsibility was delegated to local governments for the planning and implementation of transportation air pollution control measures in urban areas. The CAA placed a special emphasis on the integration of air quality considerations into the ongoing transportation planning process currently funded by the Federal Highway Administration, Urban Mass Transportation Administration, and the State of Michigan. Specifically, Metropolitan Planning Organizations (MPO) were cited as being the appropriate agencies in most states to perform the transportation planning tasks required in the CAA.

The EPA provided funding to MPOs to conduct air quality analyses and choose transportation projects to improve air quality. Each MPO made a SIP commitment to evaluate the eighteen transportation control measures listed in Section 108(f) of the CAA. The following table lists the control measures:

Clean Air Act Transportation Control Measures

1 Motor vehicle emission inspection and maintenance programs;

2. Programs to control vapor emissions from fuel transfer and storage operations and operations using solvents;

3. Programs for improved public transit;

4. Programs to establish exclusive bus and carpool lanes and areawide carpool programs;

5. Programs to limit portions of road surfaces or certain sections of the metropolitan areas to the use of common carriers, both as to time and place;

6. Programs for long-range transit improvements involving new transportation policies and transportation facilities or major changes in existing facilities;

7. Programs to control on-street parking;

8. Programs to construct new parking facilities and operate existing parking facilities for the purpose of park and ride lots and rural carpool parking lots;

9. Programs to limit portions of road surface or certain sections of the metropolitan area to the use of non-motorized vehicles or pedestrian use, both as to time and place;

10. Provisions for employer participation in programs to encourage carpooling, vanpooling, mass transit, bicycling, and walking;

11 Programs for secure bicycle storage facilities and other facilities, including bicycle lanes, for the convenience and protection of bicyclists, in both public and private areas;

12. Programs of staggered hours of work;

13. Programs to institute road user changes, tolls, or differential rates to discourage single occupancy automobile trips;

14. Programs to control extended idling of vehicles;

15. Programs to reduce emissions by improvements in traffic flow;

16 Programs for the conversion of fleet vehicles to cleaner engines or fuels, or to otherwise control fleet vehicle operations;

17. Programs for retrofit of emission devices or controls on vehicles and engines, other than light duty vehicles, not subject to regulations under Section 202 of Title II of this Act; and

18. Programs to reduce motor vehicle emissions which are caused by extreme cold start conditions.

Source: Clean Air Act as Amended 1977

Transportation planners will recognize many of these measures as transportation system management actions. This list is the source of the EPA's concept of "Reasonably Available Control Measures" (RACM) for transportation sources of pollutants. In the body of this report, a RACM is a particular transportation air quality control measure that is either listed in the CAA or is "reasonably available" based on evaluations performed by transportation planners. RACM analysis is the basis for a Transportation Control Plan.

2.4 Transportation Control Plans

The Transportation Control Plan (TCP) is required by the EPA as an urban area's SIP commitment to specific transportation projects. The projects are to be implemented over a five year period and must contribute to the attainment of the federal ambient air quality standards by the statutory 1987 deadline. The RACM analysis must also justify the rejection of any measures identified as reasonable in the CAA.

The TCP requirement is triggered if the State Air Quality Agency estimates that an urban area will be in non-attainment after 1982, and requests an extention to 1987. Currently, urban Detroit is the only Michigan area in this category. Therefore, Detroit will submit a TCP to the EPA in 1982. Other urban areas with populations greater than 200,000 must consider all RACMs, and implement those that can reasonably be implemented to reach attainment by 1982. A transportation control plan must contain the following elements:

1. Analysis of "Reasonably Available Control Measures" listed in Section 108(f) of the Clean Air Act;

2. Documentation of the technical evaluation methods and review procedures;
3. A list of transportation projects or packages of projects to be implemented between 1982 and 1987;
4. Tentative schedules for implementation;
5. Identification of how the projects will be incorporated in the urban area's Transportation Improvement Program (TIP), if the projects are not already included;
6. Justification for not implementing particular control measures.

The EPA provided guidance about the nature and level of analysis required for Clean Air Act Section 108 measures in a letter dated October 9, 1980. In this letter, the EPA indicates that "the type of analysis of transportation measures is related to the magnitude of the air quality problem in an urban area." The June 1978 EPA-DOT Transportation Air Quality Guidelines are cited as follows:

> "Consistent with DOT's joint planning regulations, the detail and resources used to develop and evaluate transportation alternatives should be commensurate with the magnitude and geographic extent of the air quality problems facing each non-attainment area. Areas with severe and persistent air quality problems should make a major effort towards finding solutions, while areas with less extensive or shorter term problems may find a lower level of effort sufficient. Region-wide air quality problems (e.g. high ozone levels) will require investigation of region-wide strategies; more localized air quality problems (e.g., high CO concentrations) may also require region-wide solutions but in some cases may only require subarea studies and corrective strategies."

The EPA considers all of the Clean Air Act Section 108 measures, as a class, to be reasonably available. This means that all of the measures must be considered for implementation, but it does not mean that they must all be implemented. Measures may be eliminated as long as the justification for doing so is documented. The need for this documentation is presented in the September 30, 1980 Federal Register. The justification consists of four elements:

1. Documentation of air quality, health, welfare, economic, energy, social, and mobility effects of the measure;
2. Determination that the adverse effects of the measure will be substantial, widespread, and long-term;
3. Determination that the measure is not reasonably available;
4. Demonstration that the air quality standards can be expeditiously attained without the measure.

Since the basis for this justification is dependent on the magnitude and extent of the air quality problem, areas with less severe air quality problems can use simple analytical techniques or, in some cases, non-quantitative techniques. In the instance of RACMs listed in Chapter IV of this handbook, no further analysis or justification must be provided. In other cases, the planner must use the literature review and analytic procedures in this handbook to reach a decision to implement a measure or to establish the justification for not implementing the measure.

It is expected that each urban area will conduct the transportation control plan analysis within the framework of the ongoing Continuing, Coordinated and Conprehensive (3C) planning framework. In addition, many projects will be proposed, reviewed, and implemented from a traffic engineering point of view with air quality improvements and fuel consumption reductions as a by-product. Projects that are components of the transportation control plan must be incorporated into the Annual Element of the Transportation Improvement Program in accordance with the schedule each urban area submits to comply with SIP requirements. The EPA has provided funds to conduct the analysis for the TCP and the Federal Highway Administration has indicated continued support for the overall Transportation System Management effort.

2.5 Relationship Between Air Quality and Transportation System Management

Air quality considerations were informally a part of the transportation project selection process prior to 1977. Transportation System Management (TSM), the implementation of short range, less capital intensive transportation projects geared toward making more efficient use of the existing transportation facilities, was formalized by the United States Department of Transportation in 1976. The CAA merged the concepts of Air Quality and TSM by establishing a list of transportation control measures in Section 108(f) of the Act, and requiring planners to evaluate the measures for possible inclusion in transportation control plans. To a great extent, TSM and air quality planning result in the choice of similar projects, although the two planning processes were implemented separately.

The United States Department of Transportation defined the TSM process in a September 17, 1976 regulation. This regulation has been implemented as follows:

A. The urban transportation planning process shall include the development of a transportation plan consisting of a TSM element and a long-range element. The transportation plan shall be reviewed annually to confirm its validity and its consistency with current transportation and land use conditions.

B. The transportation system management element of the transportation plan shall:

1. Provide for the short-range transportation needs of the urbanized area by making efficient use of existing transportation resources and providing for the movement of people in an efficient manner; and

2. Identify traffic engineering, public transportation, regulatory, pricing, management, operational and other improvements to the existing urban transportation system not including new transportation facilities or major changes in existing facilities.

Specifically, TSM concentrates on providing for short-range transportation needs through the efficient use of existing resources. The intent of TSM is to maintain mobility in the most cost-effective manner. In many cases, planners will find this consistent with air quality goals. For example, in an urbanized area, a transit bus could hinder the flow of traffic by stopping in the right lane to pickup or drop off passengers. On a two-lane road, this results in the traffic being blocked completely. A TSM activity in such an instance would be to make curb cuts to enable buses to pull in to pick-up and drop-off passengers.

This, would result in smooth traffic flow, with less delay and subsequently lower emissions. This is an example of a TSM project that is also an air quality project. Not all transportation control measures, as defined by the Clean Air Act, are TSM actions. Table 2-1 is an abbreviated list of CAA measures which will be used throughout the remainder of the handbook. The measures have been categorized to note which are usually considered TSM activities.

2.6 Energy Considerations in Transportation Control Planning

The Clean Air Act requires that energy consumption be considered when choosing transportation projects. In addition, Executive Order 12185 of 1979 requires that energy conservation be incorporated into the urban transportation planning process.

Most of the Clean Air Act transportation control measures and most TSM measures are linked to improving the efficiency of travel. When emission reductions are achieved, fuel consumption reductions are achieved simultaneously. For these reasons, energy consumption calculations were incorporated into the handbook.

TABLE 2-1 Transportation Control Measures

Transportation Control Measures	TSM(Yes/No)
1. Inspection/Maintenance Programs	No
2. Vapor Recovery	No
3. Improved Public Transit	Yes
4. Exclusive Bus and Carpool Lanes and Area-Wide Carpool Programs	Yes
5. Common Carrier Restrictions	Yes
6. Long Range Transit Improvements	Yes
7. On-Street Parking Controls	Yes
8. Park and Ride and Rural Carpool Parking Lots	Yes
9. Private Vehicle Restrictions & Pedestrian Malls	Yes
10. Employer Based Carpool Programs	Yes
11. Programs to Encourage Bicycling	Yes
12. Staggered Work Hours	Yes
13. Road Pricing to Discourage Single Occupancy Auto Trips	Yes
14. Controls on Extended Vehicle Idling	No
15. Traffic Flow Improvements	Yes
16. Alternative Fuels or Engine or Other Fleet Vehicle Controls	No
17. Other than Light Duty Vehicle Retrofit	No
18. Extreme Cold Start Emission Reduction Programs	No

CHAPTER III

EVALUATION OF REASONABLY AVAILABLE TRANSPORTATION CONTROL MEASURES

3.1 How RACMs Change Travel Characteristics

Transportation control measures change the way vehicles travel by improving their average speed, decreasing the number of vehicle miles traveled, or decreasing travel time. These changes result in improved vehicle emission rates and fuel consumption rates. In this chapter, each of the Clean Air Act RACMs will be evaluated. A key element of determining the air quality and fuel consumption impacts will be the change in travel characteristics prompted by the measure.

Figures 3-1 and 3-2 illustrate the relationships between speed changes and emission rates, and speed changes and fuel consumption rates. Note that increases in average speed from 10 to 15 mph decreases emissions more than an improvement from 40 to 45 mph. The same relationship is true for fuel consumption.

Several of the RACMs have the ability to change average vehicle speeds. In these cases, the RACM analysis will provide methods to quantify these speed changes and associate them with changes in emissions and fuel consumption rates. The handbook calculation methods are based on extensive computer modeling to simulate actual travel conditions. An example of this type of transportation control measure is RACM 15; Traffic Flow Improvements.

Transportation control measures may also reduce emissions and fuel consumption by eliminating vehicle miles of travel. VMT can be reduced by eliminating trips or by diverting trips to more efficient modes. The handbook methods for determining the extent of VMT reductions varies. In some cases, the handbook calculations are based on computer simulations of changes in auto occupancy due to ridesharing. In other cases, the estimates are based on literature review information and technical judgement. In these instances, VMT reductions are estimated as a percent reduction in areawide travel. Examples of these transportation control measures are RACM 10, Employer Based Ridesharing Programs, and RACM 8, Park-and-Ride and Rural Carpool Parking Lots.

The third method of reducing emissions is decreasing travel time. This happens when traffic flow is improved or when changes to the transportation system cause reductions in vehicle idling or overall delay. It also occurs when reductions in the number of vehicles on a particular route results in reduced travel times for the remaining vehicles. Examples of this type of transportation control measure are RACM 3, Improved Public Transit, and RACM 12, Staggered Work Hours. Improved transit removes private vehicles from the road, reducing travel time for the remaining vehicles. Staggered work hours spread out the peak travel hours and reduce delay.

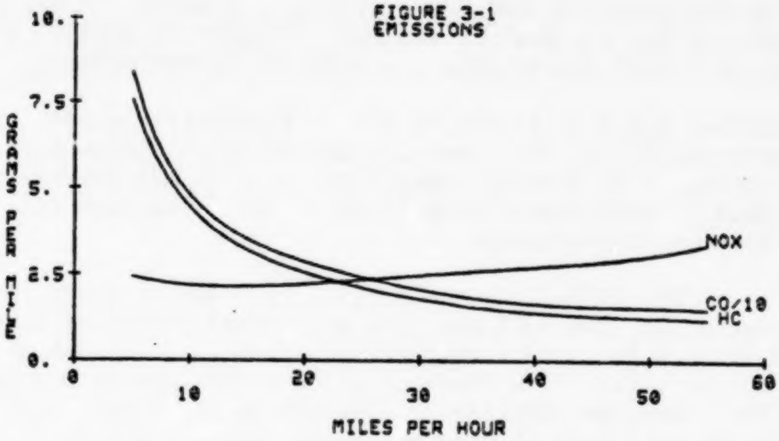


FIGURE 3-1
EMISSIONS

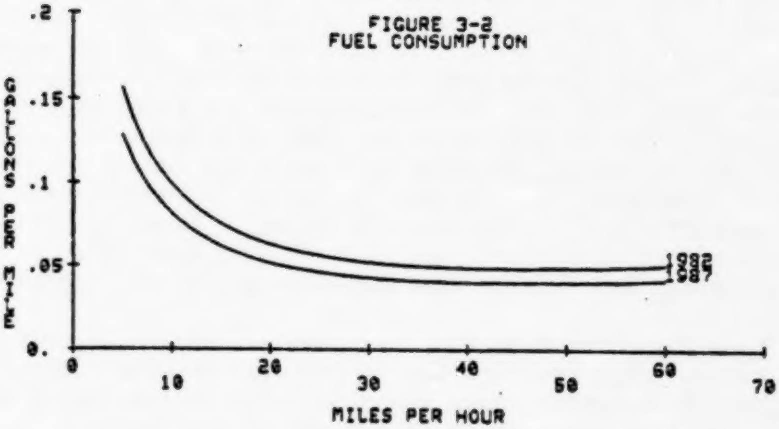


FIGURE 3-2
FUEL CONSUMPTION

3.2 Packaging Control Measures

Consideration must be given to implementation of coordinated "packages" of control measures. This requires weighing various measures since the combined effects of the "package" may be greater or smaller than the effect of a measure implemented alone. In some cases, a particular measure may even produce an outcome that runs contrary to the expected result. For example, if a freeway lane is set aside for high occupancy vehicles and causes other lanes to become congested, the goals of improving mobility and air quality have not been met. It is important that the predicted results take into consideration the unique characteristics of an individual urban area.

3.3 Data Required To Use This Handbook

The data listed in Table 3-1 must be collected before using the procedures to quantify emissions and fuel consumption impacts of individual RACMs presented at the end of each section of Chapter III. The list is not a complete representation of all of the information needed to fully evaluate measures. Specific urban area political, economic, and institutional situations must also be considered.

The type of analysis needed will vary, depending on the RACM. In some cases, it may be more important to estimate the nature of the probable impacts before considering their magnitude. For others, a quantification of benefits is a key to their cost effectiveness, and may determine the feasibility of implementation.

Meaningful analysis techniques which result in the accurate quantification of impacts are not available for all control measures. Planning and engineering judgement is important in evaluating the application of measures presented in the literature review to determine if similar outcomes can be expected in other urban areas.

TABLE 3-1

DATA THAT SHOULD BE COLLECTED BEFORE USING THIS HANDBOOK

RACM		Date Needed
# 8	Park and Ride and Rural Carpool Parking Lots	Location of proposed lots, distance from the urban area boundry, distance from the CBD
		Urban area VMT
		Estimate of potential rural carpool parking lot patronage (if possible)
#10	Employer-based Carpooling and Vanpooling	Operating statistics on existing employer-based programs
		Estimate of potential new riders in employer-based ridesharing programs (if possible)
#15	Traffic Flow Improvements	Identification of key bottleneck corridors or intersections for more detailed study
		Characterization of bottlenecks: --current signalization, lanes, channelization --current delays and traffic volumes --v/c ratios or level of service --one-way and two-way streets --cross traffic and turn ratios --spacings among intersections
# 3, 6	Short and Long Range Transit Improvements	Current transit statistics: --ridership
		Estimate of potential future transit ridership increases (if possible)

RACM		Date Needed
# 4	Area-Wide Carpool Programs	VMT for the urban area and CBD Current carpool ridership Estimate of potential new carpool ridership (if possible)
# 7	On-Street Parking Controls	Current level of service v/c ratios on streets where parking may be removed Estimate of reasonable choice of on-street spaces to remove
# 5, 9	Common Carrier Restrictions, Private Vehicle Restrictions and Pedestrian Malls	Location and area size of pedestrian malls and auto free zones CBD VMT - current Regional VMT - current Year of completion of project
#11	Programs to Encourage Bicycling	Current bicycle trips as a percent of total trips

3.4 Organization of RACM Analysis

The RACMs are presented in the following order; each as a separate section in Chapter III:

RACM #		Page
1	Inspection/Maintenance	3 - 1 - 1
8	Park and Ride & Rural Carpool Parking Lots	3 - 8 - 1
5 9	Common Carrier Restrictions Private Vehicle Restrictions and Pedestrian Malls	3 - 9 - 1
11	Programs to Encourage Bicycling	3 - 11 - 1
12	Staggered Work Hours	3 - 12 - 1
16	Alternative Fuels	3 - 16 - 1
15	Traffic Flow Improvements	3 - 15 - 1
10	Employer Based Ridesharing Programs	3 - 10 - 1
4B	Areawide Carpool Programs	3 - 4B - 1
7	On-Street Parking Controls	3 - 7 - 1
3	Improved Public Transit	3 - 3 - 1
6	Long Range Transit Improvements	3 - 6 - 1

Chapter IV will present the rationale for excluding certain RACMs from further consideration. They are presented in the following order:

RACM #		PAGE
2	Vapor Recovery	4 - 1
4A	Exclusive Bus and Carpool Lanes	4 - 3
13	Road Pricing To Discourage Single Occupancy Auto Trips	4 - 4
14	Controls on Extended Vehicle Idling	4 - 5
17	Emission Control Retrofit for Other Than Light Duty Vehicle Retrofit	4 - 6
18	Extreme Cold Start Emission Reduction Programs	4 - 8

CHAPTER IV

EXCLUSION RATIONALE

4.1 Introduction

This section details the reasons for exclusion of particular RACMs under either of the two categories mentioned below:

1. Excluded from consideration statewide owing to legal barriers or inappropriate applications;

2. Excluded from consideration in metropolitan areas where insufficient travel densities prohibit successful implementation.

It should be pointed out that the elimination of a measure does not mandate its deletion from further consideration by local planning agencies. Through an agreement between the EPA and MDOT, when information required to estimate RACM impacts is lacking, or for when legal, technical, or analytical obstacles render implementation unlikely, no additional justification need be provided by individual agencies.

4.2 RACM No. 2 - Vapor recovery from fuel transfer and storage operations.

Handbook Exclusion - All nonattainment areas

Rationale - Not a transportation measure subject to implementation through local "3C" activities.

4.3 Discussion

The EPA has proposed that effective control of evaporative hydrocarbon emissions at gasoline filling stations should include capturing vapors that escape while gasoline is pumped into vehicle tanks. Most stations are presently equipped with vapor recovery systems associated with tanker truck filling of submerged storage vessels. As these storage tanks are filled, residual hydrocarbon vapors are displaced and attempt escape to the ambient air. Because of this, a pipe or hose is placed directly into the tanker truck to replace the evacuated liquid gasoline. This vapor balance procedure is termed "stage one" vapor recovery.

"Stage two" recovery extends this concept to retail gasoline sales at the pump. In one proposed scenario, the filler nozzle and pump hose would have a dual channel; one to feed petroleum and the other to "inhale" fugitive hydrocarbons from vehicle tanks. These hydrocarbon vapors would replace the petroleum evacuated from underground storage. In another scenario, automobiles and trucks would be equipped with a special chamber to draw off and store hydrocarbon vapors as the gas tank is filled. These vapors would then be channeled to the carburetor once the engine is in operation and ignited as fuel. "Stage two" is an energy conservation measure as well as an emission reduction measure.

If "stage two" vapor recovery is implemented in Michigan, it will likely be pursuant to a state regulation concerning maximum permitted emissions from retail gasoline sale outlets, classified as stationary sources. Other fuel transfer and storage operations, including storage and loading at terminals, 40,000-gallon bulk plants, refineries, and any other facility handling 20,000 gallons or more per day will be covered by proposed new rules for vapor control in the Michigan State Implementation Plan.[1] Promulgation of "stage two" regulations would probably rely on two conditions being met:

1) the determination that a reliable technology has been developed either for pump feed or on-board vapor recovery, and

2) demonstration that this additional increment of hydrocarbon control is required to attain the ozone standard by 1987.

An individual municipality or county could pass an ordinance requiring stage two devices be installed at all retail gasoline outlets doing business under its jurisdiction. However, the imposition of this cost burden upon only a segment of the total gasoline dealer population could have negative economic impacts Costs would be passed to consumers who are likely to transfer their business to more competitively-priced dealers outside the affected jurisdiction.

In no event could stage two vapor recovery at gasoline stations be considered a measure subject to implementation through the traditional transportation/ air quality planning process. It requires imposition of controls on private sector activities that would have to be brought about by law or through an ordinance, rather than simply through allocation of public money. Vapor recovery has no bearing on vehicle miles of travel, vehicle trips, or traffic flow conditions, and is functionally related to these parameters only through the weak connection of total gallons of gasoline sold. If drivers who are responsible for most of the travel in affected counties elect to purchase fuel outside "stage two" counties, expected hydrocarbon emission reductions will not be achieved where it is needed. Therefore, retail gasoline sales fall outside the domain of the continuous, coordinated, and comprehensive (3C) planning performed by local agencies.

4.3 RACM NO. 4A - Exclusive bus and carpool lanes

Handbook Exclusion - Nonattainment regions outside Detroit metro area

Rationale - The radial component of daily traffic flow is insufficient to promote significant modal diversion in outstate metro areas. Outstate side roads are not appropriate for this measure because high-capacity road congestion is not a chronic problem outstate.

4.4 Discussion

Highway lanes set aside for the exclusive use of shared and multi-rider vehicles have been proposed as an effective means of reducing total vehicle trips during peak-hour operating conditions. They have been identified as having high potential to improve localized CO air quality.[2] As experience in several large urban areas has shown, such lanes provide a strong incentive for motorists to demonstrate that ride-sharing is taking place. The combined effect of relative free flow for buses and carpools on an exclusive freeway lane, and often severe congestion in the remaining private car lanes, has been sufficient to divert a significant number of radial journey-to-work commuters to multi-rider modes in locations as diverse as Washington, D.C., San Francisco, and the Miami metropolitan area.

Metropolitan areas where exclusive lanes have enjoyed modest success share at least two characteristics. First, all have one or more high-capacity freeway feeding downtown areas, over which a significant proportion of the area's work trips move daily. Second, a period of heavy congestion regularly occurs during morning and evening peak commuting periods. These conditions do not simultaneously apply to outstate Michigan metropolitan areas. With the possible exception of Flint, by far the greatest portion of radial work travel in the larger outstate cities takes place on the arterial systems, and traffic flows smoothly except for extremely brief morning and afternoon peaks.[3]

Arterials are generally not appropriate for long-distance exclusive lanes unless costly bus and carpool signal pre-emption or phasing has been implemented over the length of the radial corridor, as in Louisville, Kentucky. Otherwise, start-stop conditions and relatively non-competitive travel speeds render the multi-rider option unattractive and thus lessen its ability to divert car drivers. Congestion in the peak direction of flow can be avoided by multi-rider vehicles if exclusive contra-flow bus lanes are provided. The apparent effectiveness of exclusive reverse-flow lanes on major one-way arterials in such cities as Madison, Wisconsin, and Los Angeles is tempered somewhat by the cost of the facilities since, in some cases, a third directional lane would have to be added. There may also be the danger to unwary pedestrians and motorists. Nevertheless, the problem of non-competitive travel time on transit can be alleviated by the reverse-flow measure if appropriate safety precautions are taken.

Experience with express lanes located in non-radial corridors has been minimal. Unless a metropolitan area has at least one concentrated employment center removed from the central business district, that is as great a trip attractor as the central business district, travel volumes on non-radial routes accessing that employment center will probably not support significant diversion to transit in the corridor. Although the interstate highways serving Flint, Grand Rapids, and Lansing have contributed to the dispersal of white-collar employment throughout the metropolitan area, no one employment center along any of these routes appears to be an appropriate target for exclusive lanes.

Exclusive bus and carpool lanes may be an appropriate air quality measure where localized CO violations are a problem in a particular corridor. They will be most successful where a substantial component of daily work travel is radially oriented and gives rise to chronic peak-period congestion, where at least one freeway feeds downtown, where a selection of six-lane (minimum) arterials is available in primary journey-to-work corridors, and where mass transit or ridesharing is an accepted or integral part of the areawide transportation system. The out-state Michigan metropolitan areas do not qualify under these criteria.

4.5 RACM NO. 13 - Road pricing to discourage single occupancy auto trips

Handbook Exclusion - All nonattainment areas

Rationale - Road tolls are prohibited by Public Act 51 of the Michigan Highway Law on all roads supported with motor vehicle highway taxes. This measure is not subject to implimentation through local 3C activities. "Control area" pricing is not appropriate for Michigan conditions.

4.6 Discussion

Maintenance of the majority of Michigan roads carrying moderate-to-high daily traffic is financed, in part, through contributions from the state motor vehicle tax. This tax accounts for a significant portion of Michigan's share in matching Federal Aid Primary, Federal Aid Secondary, and Federal Aid Urban System funds.

Without the tax, many roads would become impassible over time unless tolls were levied for their upkeep. The Michigan Highway Law stipulates that the motor vehicle tax supports the interstate network and that "pay-as-you-go" tolls cannot simultaneously be in place on any road in the state. By federal law, new tolls ay not be levied on any part of the interstate system. Without a change in basic legislation (i.e. repeal or amendment of Act 51), it is not possible to implement selective road pricing in Michigan. Either state-supported roads become toll facilities, or none do.

If an individual county or municipality elects to institute road pricing on facilities supported by county or local property/sales taxes, it may have to seek support for a new enabling ordinance. In any case, volumes and capacities on these roads would likely not warrant such a measure, and tolls may succeed only in diverting the entire traffic volume to the "free" state system. If not, vehicles continuing to use the facility would operate at lower-efficiency, higher-polluting average speeds owing to the stop-start of toll collection at booths.

As with vapor recovery, we are dealing with an air quality measure not subject to implementation and enforcement through local 3C activities. An exception is an action taken independently by a member municipality that must be approved by an association of local governments meeting as a body. Such cases are expected to be extremely rare, and technically are not the province of 3C planning. Other local initiative "control areas" pricing schemes, such as the Singapore program requiring purchase of a monthly pass to enter the controlled area, are applicable where there is extreme local congestion for much of the day. This is not experienced in Michigan, and probably ineffective except as a measure to combat intense CO hotspots.

4.7 RACM NO. 14 - Controls on extended vehicle idling

Handbook Exclusion - Nonattainment region outside Detroit metropolitan area

Rationale - This is primarily a fleet-oriented, cold weather CO measure not enforceable on, or appropriate to, individual motorists, except to educate them that prolonged warm-up may not be necessary. The fleet population is low in outstate areas. Other measures to reduce vehicle idling are treated as traffic flow improvements under RACM No. 15.

4.8 Discussion

It has been common practice for heavy trucks involved in construction, cartage, and other commercial and industrial activities to be kept running over long periods while not on duty in order to keep the engines warmed up and in ready condition. Engine idling of this nature is especially pronounced during winter months, when heavy diesel engines may be very difficult to start. Where fleet truck operations are taking place in the vicinity of sensitive receptors (schools, hospitals, residences, office buildings, or other locations for which an individual or individuals is/are likely to be located for eight consecutive hours), localized CO problems may develop. At downtown and airport locations where taxi ranks form, there is a similar (although more limited) likelihood. Controls on truck and taxi fleet idling would be capable of implementation through 3C activity, though difficult to enforce.

The need for idling controls as a regional measure has not been established for outstate areas of Michigan. Fleet operators are increasingly cutting back on truck idling in order to conserve fuel, and taxi ranks do not appear to be of major importance in smaller metropolitan areas. If prolonged idling of private cars is a problem on cold mornings or evenings, the appropriate solution would be a modest public information effort to remind the public that extended warm-up is unnecessary and penalizes fuel economy.

Idling is both voluntary and involuntary. Involuntary idling is a function of delays in traffic flow. Vehicle queues at traffic signals and bottlenecks are examples of involuntary idling. The incidence of idling in this context may be reduced by measures to improve the efficiency of traffic flow. Such measures and their impact are considered under RACM No. 15.

Measures to control extended (voluntary) vehicle idling are appropriate to CO nonattainment areas or locations in which chronic CO "hotspots" have been linked to major fleet-in-readiness operations, or where it is common practice for motorists to leave their engines running to prevent freeze-up, as in the extreme wintertime cold of Alaska. Voluntary idling is likely to become an infrequent practice as gasoline prices climb. Involunary idling must be addressed with measures to improve the flow of on-street traffic.

4.9 RACM NO. 17 - Other than light duty vehicle retrofit

Handbook Exclusion - All nonattainment areas

Rationale - This is a measure that is costly to the private sector and effective only where heavy-duty gasoline trucks contribute more than five percent of the regional VMT. It is difficult and expensive to enforce, and may lead to relocation of truck fleets to "non-retrofit" areas.

4.10 Discussion

Depending on driving conditions, heavy gasoline-powered trucks (greater than 8500 lbs. GVW) may emit three to ten times the amount of pollutant released by automobiles. This ratio will decline in the future with the introduction of more stringent emission standards on new model year trucks.

In the near term, the disparity will continue to be a cause of concern where heavy gasoline trucks experience heavy use. In northwestern Indiana, for example, heavy gasoline trucks experience heavy use and contribute up to 25 percent of mobile-source emissions of hydrocarbons and carbon monoxide, while accounting for about ten percent of total vehicle miles of travel.[4]

The technology to reduce exhaust emissions from heavy-duty vehicles is available, but at nonniform levels of refinement. In all cases, retrofit devices are relatively expensive. They are not currently mass-produced, and a few are in the prototype stage. Four basic types of devices are deemed effective on heavy-duty vehicles. These are:

1. Oxidation catalyst with air pump.
2. Air bleed
3. Lean mixture carburetor
4. Exhaust gas recirculation

Significant technical problems are associated with the use of monolithic and pellet-type catalytic converters on heavy vehicles. These include overheating (burnout) and ignition of over-rich exhaust mixtures downstream of the converter during deceleration. The former problem has been addressed through addition of a bi-metallic temperature switch to cut off secondary air supply, and the latter has largely been solved in most systems by inclusion of a diverter valve. Converter systems are generally not applicable to 1970 model year and older trucks, and there is no mass-produced control system currently on the market. Therefore, although prototype catalyst systems have been credited with achieving upto an 85 percent reduction of per vehicle CO and HC exhaust emissions, each vehicle operator would have to commit a sizeable investment to the assembly of a workable system.

Air bleeds and lean mixture carburetors are both directed to maintenance of a lean air/fuel mixture during combustion. Air bleeds automatically interrupt the intake manifold vacuum during the high vacuum modes of idle and deceleration, thus preventing too rich a burn. One such device produced an 11.8 percent reduction of HC and a 56.2 percent reduction of CO emissions. Lean mixture carburetors simply restrict the tolerances on variation of the air/fuel ratio through all modes. Most late-model truck engines are equipped with carburetors that control combustion to a leaner mixture than their predecessors. Older vehicles would have to be retrofit with equipment built to the non-stringent tolerance. Lean carburetion has been shown to reduce HC by about 11 percent and CO by 27 percent per vehicle.

Exhaust gas recirculation (EGR), which introduces a quantity of non-reactive gas into the combustion chamber to reduce the peak combustion temperature, is directed to the control of oxides of nitrogen (N), and is not directly applicable to Michigan non-attainment conditions. EGR systems in heavy-duty gasoline trucks tend to reduce CO and NOx emissions at the expense of increased HC output.

The required adoption of any of the systems discussed above would involve monetary outlay by most heavy gasoline truck owners in the private sector, and may tend to be regressive in its application. For this reason, retrofit is an expensive measure and difficult to enforce, as it would require some form of sticker display, proof of compliance at annual registration, systematic roadside sampling, and/or periodic unannounced checks at fleet depots. Even the most rigorous measures will not control emissions from trucks not registered in the control area. The net result on fleet operators might be to drive them from jurisdictions requiring retrofit to financially more attractive headquarter locations and depot sites. Offsetting air quality benefits are not likely to warrant the combined costs of implementation and enforcement of retrofit unless it is established that the CO and HC emissions contributed by heavy duty trucks in the area are well above the norm (i.e., about 10 to 15 percent of total emissions) for a multial mobile source emissions inventory.

4.11 RACM NO. 18 - Extreme cold start emission reduction programs

Handbook Exclusion - All nonattainment areas

Rationale - This is potentially costly and of questiable applicability to Michigan conditions.

4.12 Discussion

Many regions in the northern tier of the United States, in particular Alaska, regularly experience extremely cold winters with periods of thermal inversion. The effect of this condition is to trap intense carbon monoxide emissions under a low mixing lid in low windspeed conditions. Winter CO emissions are more intense because of increased combustion activity for space heating and because motor vehicles exhaust greater quantities of CO per mile than in warm weather. Vehicle cold starts are also intensified by cold weather to the point that downtown areas and other locations of high parking density chronically experience violations of the ambient CO standard during peak periods of vehicle startup after prolonged engine-off conditions. Fairbanks, Alaska is combating this extreme cold start problem by providing plug-in engine block heaters at parking places. In Minneapolis, heated ramp parking stalls for long-term parking in the central business district are projected to reduce cold start CO emissions by up to 76 kilograms per day in 1983.[5]

Although severe winters are not uncommon in Michigan, the actual contribution of extreme cold-starting conditions in the Metro Detroit CO nonattainment area has not been identified. Therefore, this does not appear to be a cost-effective measure. First year capital and operating costs of $55,000 (1979 dollars) for the Minneapolis program would bring about a net reduction of 62 kilograms per day, or $887 per kilogram removed. This compares to $760 per kilogram removed per day for an Inspection/Maintenance program.[6] If highly-concentrated pockets of long-term parking are identified as localized sources of CO emissions during morning or evening peak periods in the Detroit nonattainment area, enginelock warmup through heated parking might be the solution for those site-specific conditions. The energy consumed to operate the plug-in stalls is largely offset by per-vehicle fuel savings resulting from start-up in a warmed condition. The decision to provide these stalls would be the prerogative of individual muncipalities, rather than a 3C organization.

References

1. Michigan Department of Natural Resources. Air Quality Division. Hydrocarbon Control, Proposed Rules 336.604 - 336.608 and 336.703 - 336.705, 1978.

2. Environmental Protection Agency. Air Quality Impacts of Transit Improvements, Preferential Lane and Carpool/Vanpool Programs, March, 1978.

3. Ibid.

4. Mobile Source Emissions Inventory, Lake and Porter Counties, State of Indiana Implementation Plan.

5. Braslau and Associates. An Evaluation of Transportation Air Quality Strategies for the Twin Cities Metropolitan Area, January, 1979.

6. Ibid.

Bibliography

1. Braslau and Associates. An Evaluation of Transportation Air Quality Strategies for the Twin Cities Metropolitan Area, January, 1979.

2. Environmental Protection Agency. Air Quality Impacts of Transit Improvements, Preferential Lane and Carpool/Vanpool Programs, March, 1978.

3. Michigan Department of Natural Resources. Air Quality Division. Hydrocarbon Control, Proposed Rules 336.604 - 336.608 and 336.703 - 336.705, 1978.

4. Mobile Source Emissions Inventory, Lake and Porter Counties, State of Indiana Implementation Plan.

CHAPTER V

TRAFFIC FLOW MODELING STRUCTURE

NETSIM SIMULATION ALTERNATIVES

EMISSION AND FUEL CONSUMPTION (MPG)

PLOTS OF INTERSECTION AND CORRIDOR RESULTS

The following figures illustrate the results of computer modeling that was used to determine the effects of implementing traffic flow improvements and corridor improvements. By plotting local information on the graphs, a transportation planner can compute the results that will be obtained from making these improvements. RACM 15, Traffic Flow Improvements, provides detailed instructions on how to use these figures as well as an explanation of the benefits which can be obtained from making these improvements.

Figure 1
Traffic Flow Improvement
Modeling Structure

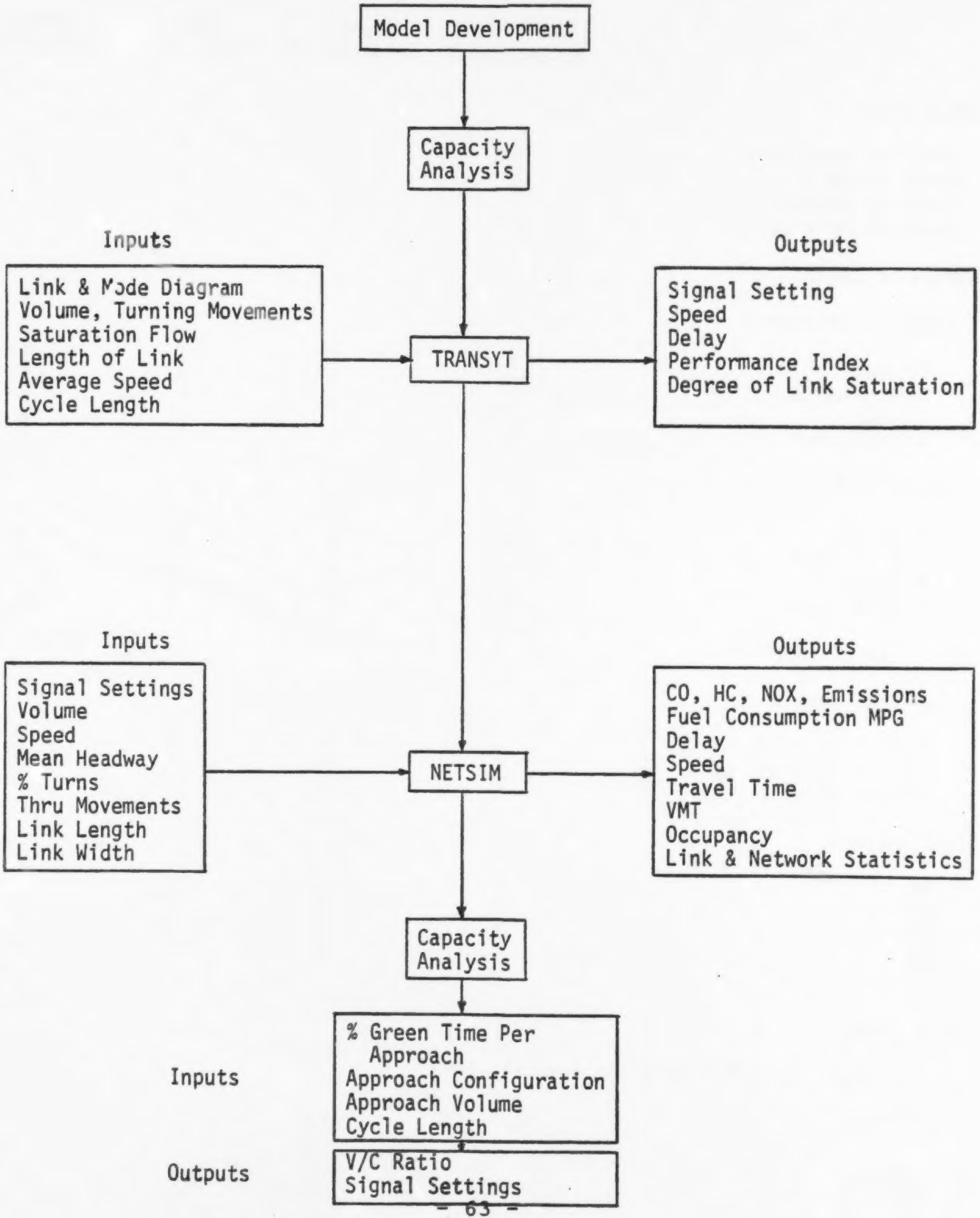

Model Development
Capacity Analysis
Inputs
Link & Node Diagram
Volume, Turning Movements
Saturation Flow
Length of Link
Average Speed
Cycle Length
TRANSYT
Outputs
Signal Setting
Speed
Delay
Performance Index
Degree of Link Saturation
Inputs
Signal Settings
Volume
Speed
Mean Headway
% Turns
Thru Movements
Link Length
Link Width
NETSIM
Outputs
CO, HC, NOX, Emissions
Fuel Consumption MPG
Delay
Speed
Travel Time
VMT
Occupancy
Link & Network Statistics
Capacity Analysis
Inputs
% Green Time Per Approach
Approach Configuration
Approach Volume
Cycle Length
Outputs
V/C Ratio
Signal Settings

Figure 2

ALTERNATIVE INTERSECTION ANALYSIS

SIMULATION MATRIX

	BAD TIMING ACTUAL SPEED	SIGNAL OPTIMIZATION	NEW TURN LANES	DEMAND ACTUATED
CONGESTION				
Level of Service B	X	X	X	X
Level of Service C	X	X	X	X
Level of Service D	X	X	X	X
Level of Service E	X	X	X	X
NUMBER OF LANES				
Level of Service D				
2 Lanes	X	X	X	X
2 to 4 Lanes	NS	X	X	X
4 Lanes	X	X	X	X
4 to 6 Lanes	NS	X	X	X
Level of Service E				
2 Lanes	X	X	X	X
2 to 4 Lanes	NS	X	X	X
4 Lanes	X	X	X	X
4 to 6 Lanes	NS	X	X	X
CROSS STREET TRAFFIC				
Level of Service C				
21% of Major-6L by 2L		X	X	X
42% of Major-6L by 4L	X	X	X	X
85% of Major-6L by 6L	X	X	X	X
TURN VOLUMES				
5%	X	X	X	X
10%	X	X	X	X
20%	X	X	X	X
40%		X	X	X

*L = Lanes

Source: NETSIM Simulation Results, 1982

Figure 3

Intersection Plot HC vs. Speed

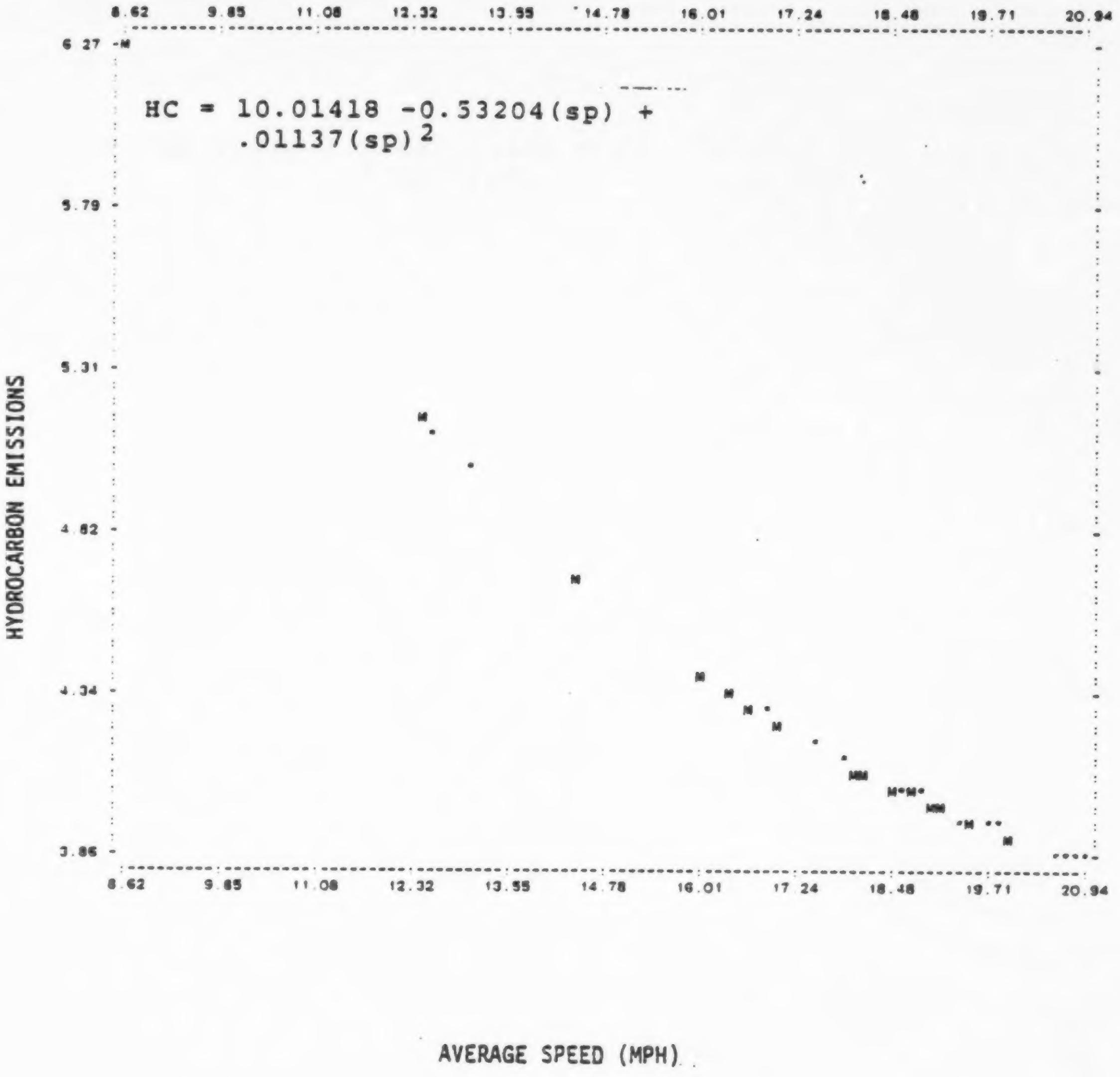


Figure 4

Intersection Plot CO vs. Speed

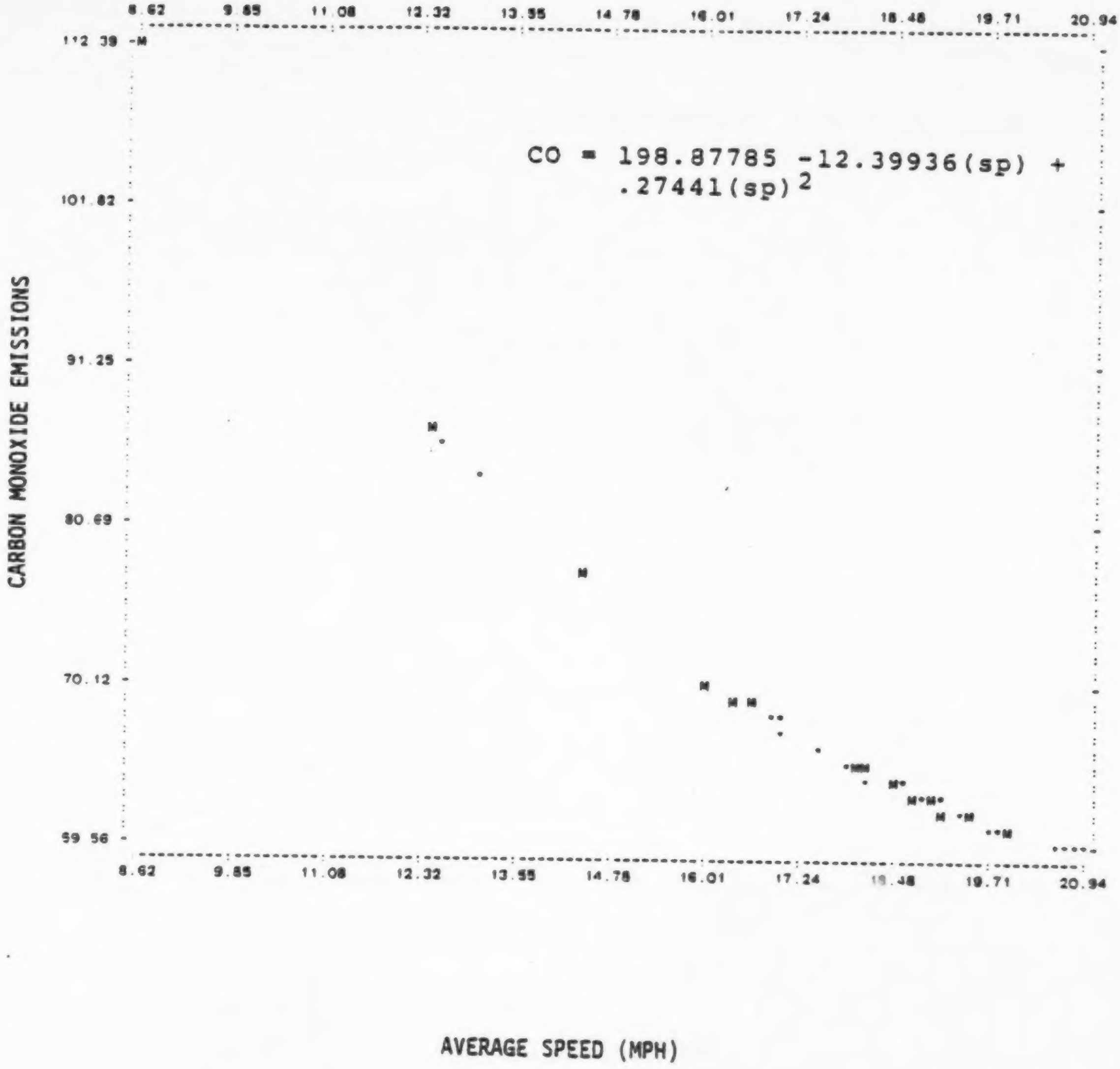


Figure 5

Intersection Plot MPG vs. Speed

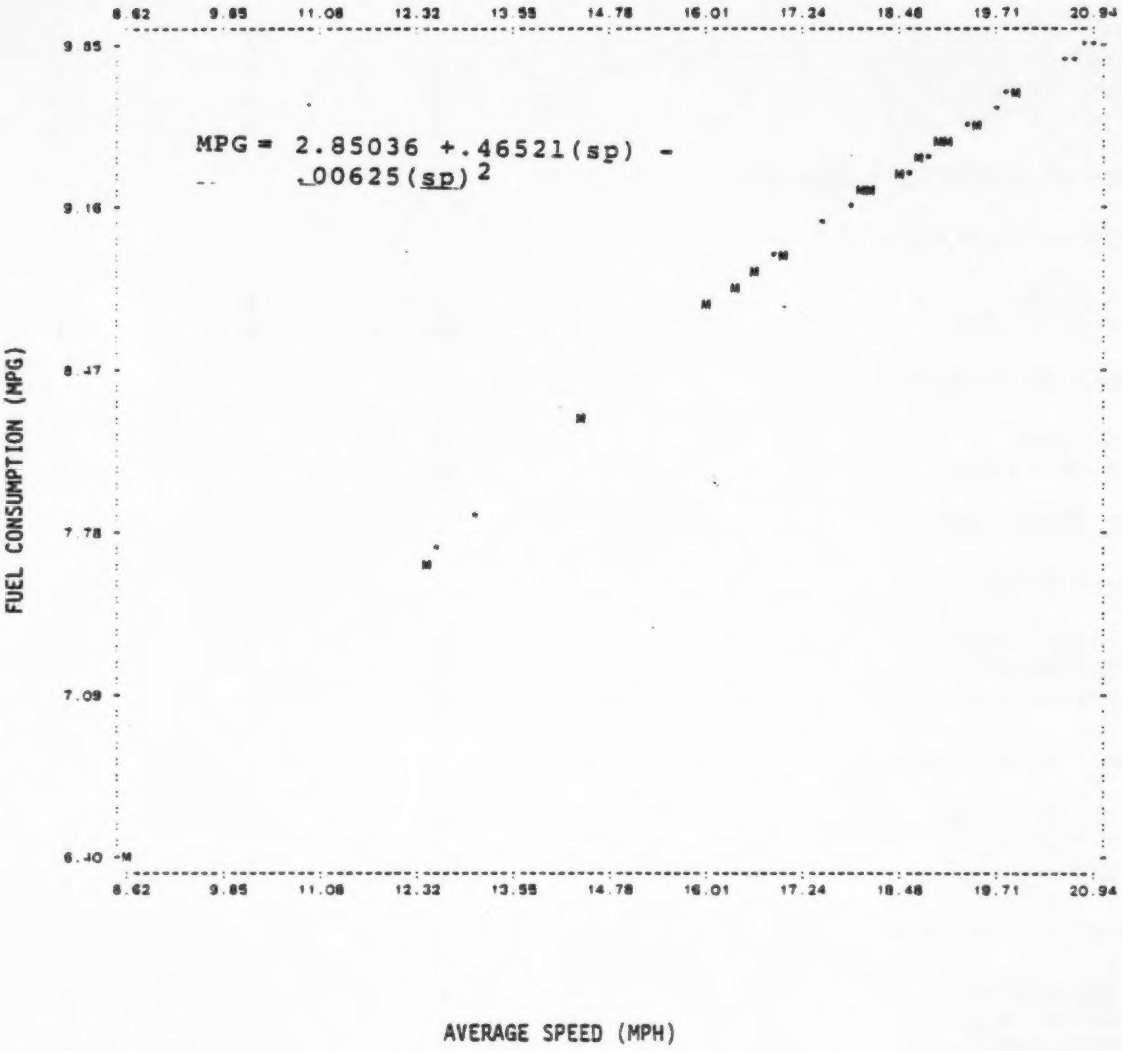


Figure 6

ALTERNATIVE CORRIDOR ANALYSIS

SIMULATION MATRIX

	BAD TIMING	SIGNAL OPTIMIZATION	NEW TURN LANES
CONGESTION			
Level of Service B	X	X	X
Level of Service C	X	X	X
Level of Service D	X	X	X
Level of Service E	X	X	X
NUMBER OF LANES-Major Approach			
Level of Service D			
4 Lanes	X	X	X
4 to 6 Lanes	NA	X	X
Level of Service E			
4 Lanes	X	X	X
4 to 6 Lanes	NA	X	X
CROSS STREET TRAFFIC			
Level of Service B			
10% of Major	X	X	X
30% of Major	X	X	X
90% of Major	X	X	X
Level of Service C			
10% of Major	X	X	X
30% of Major	X	X	X
90% of Major	X	X	X
Level of Service D			
10% of Major	X	X	X
30% of Major	X	X	X
90% of Major	X	X	X
SIGNAL SPACING			
Level of Service C			
330 Feet	X	X	X
660 Feet	X	X	X
990 Feet	X	X	X

Source: NETSIM Simulation Results, 1982

Figure 7

Corridor Plot HC vs. Speed

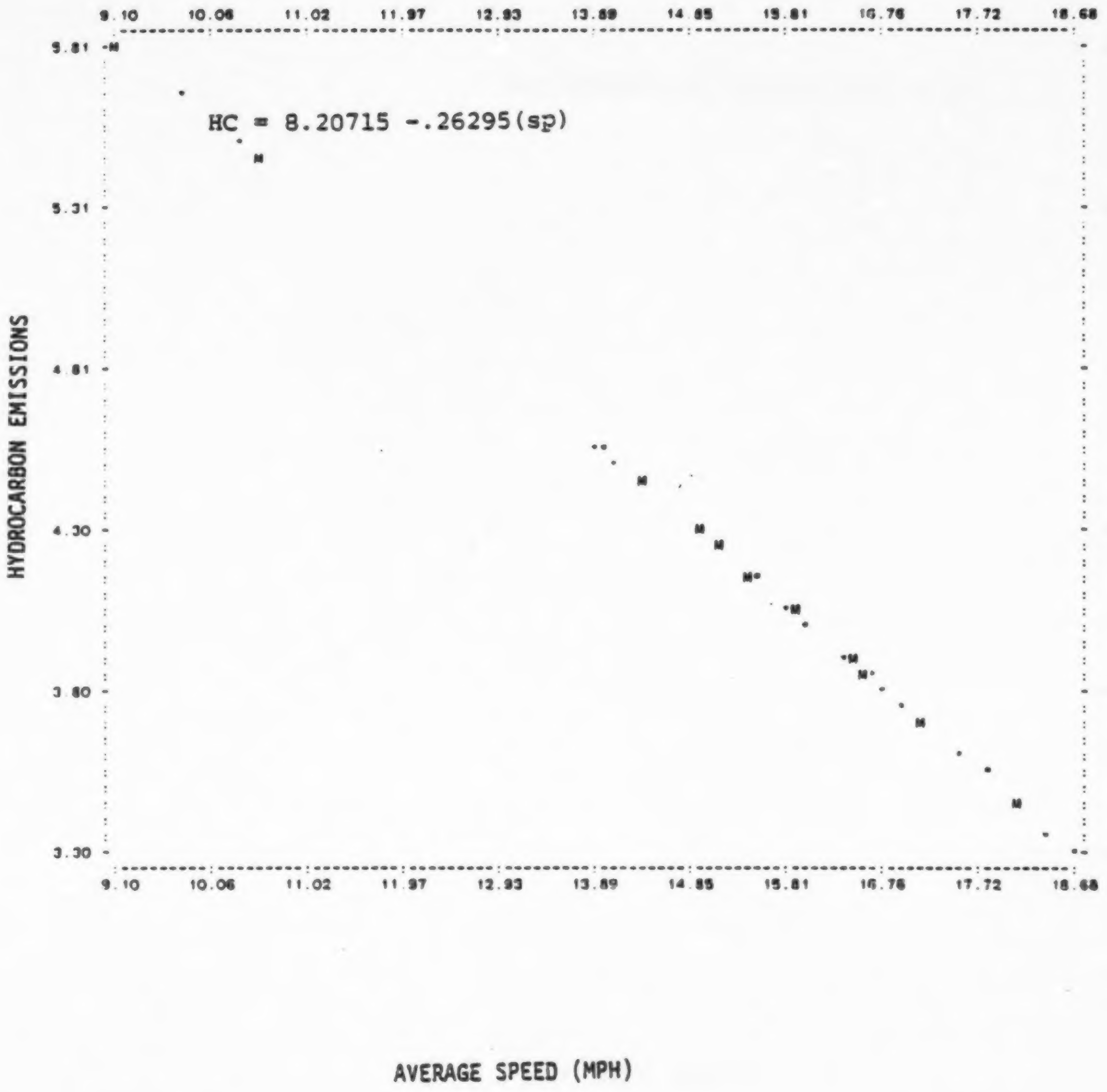


Figure 8

Corridor Plot CO vs. Speed

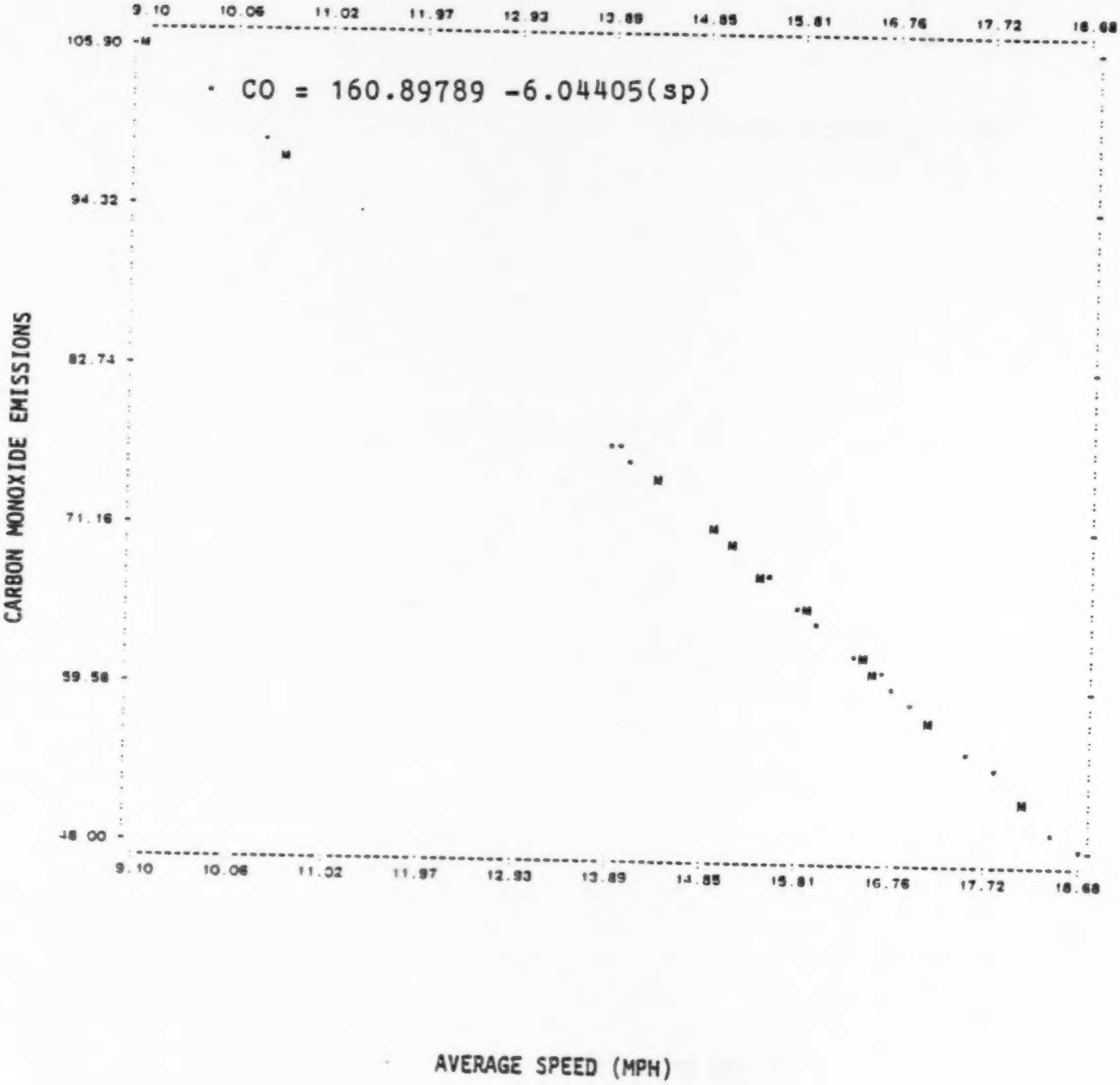


Figure 9

Corridor Plot MPG vs. Speed

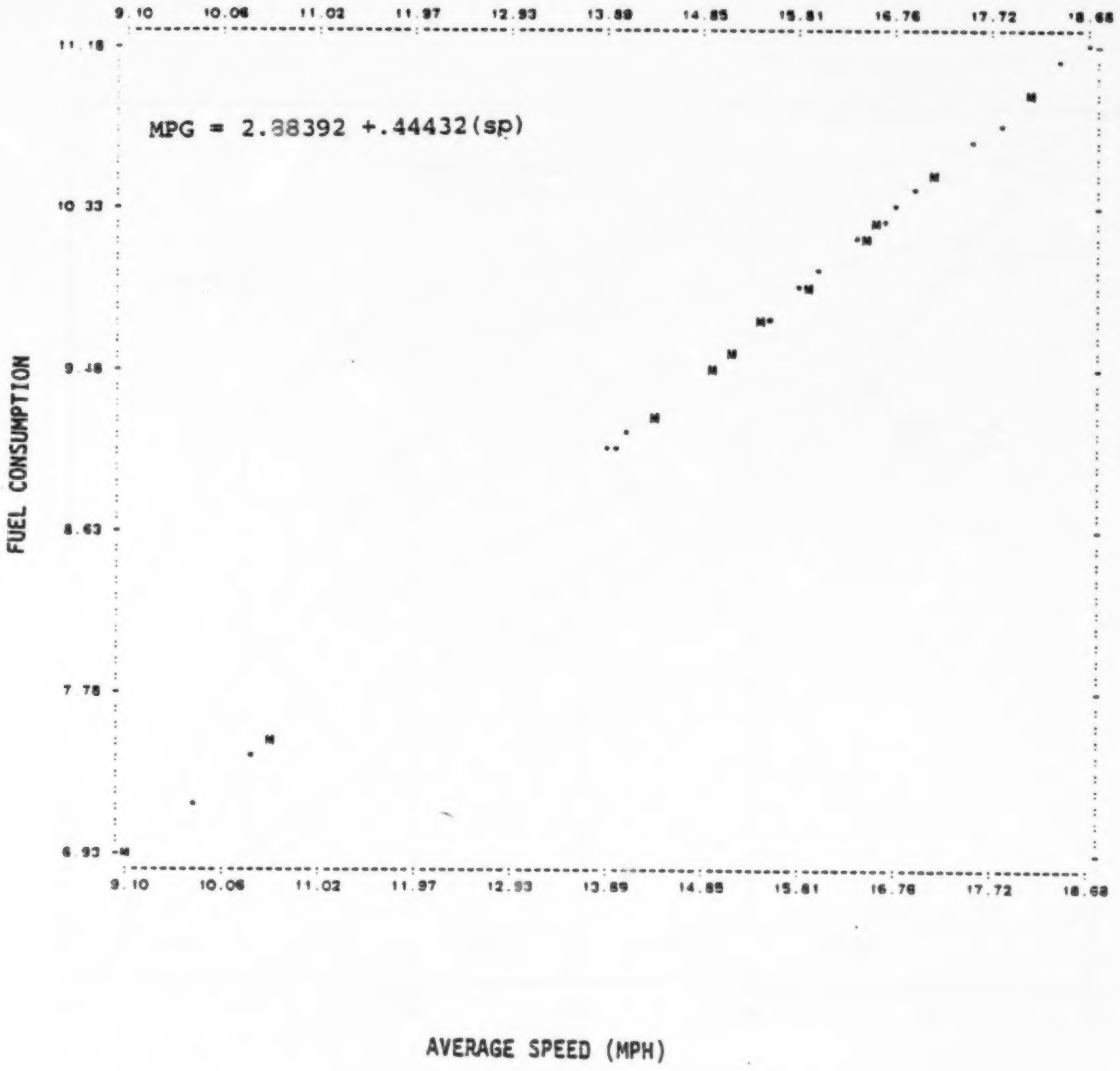


FIGURE 10

AVERAGE SPEEDS & V/C RATIOS FOR THE THREE LEVELS OF CORRIDOR TRAFFIC CONTROL

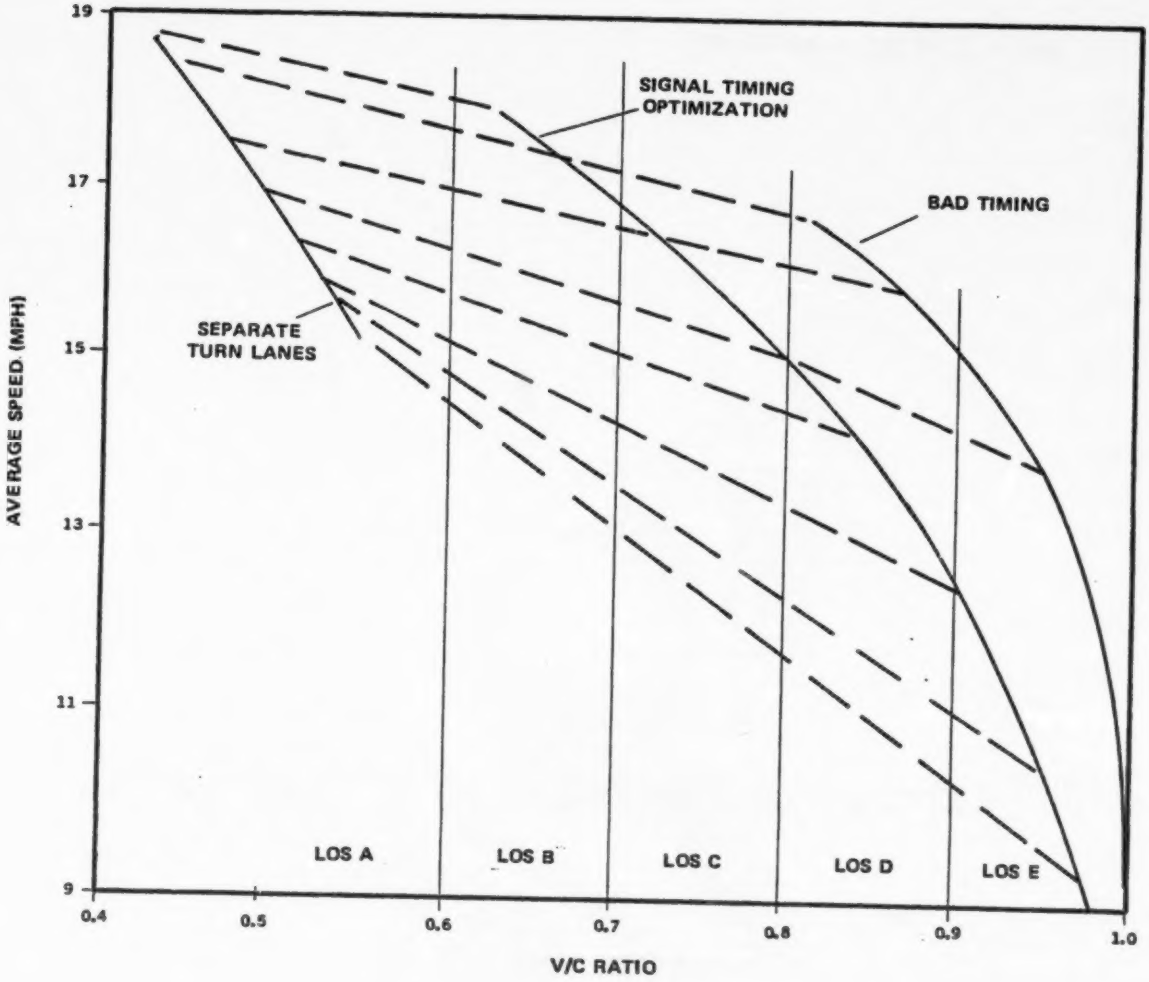
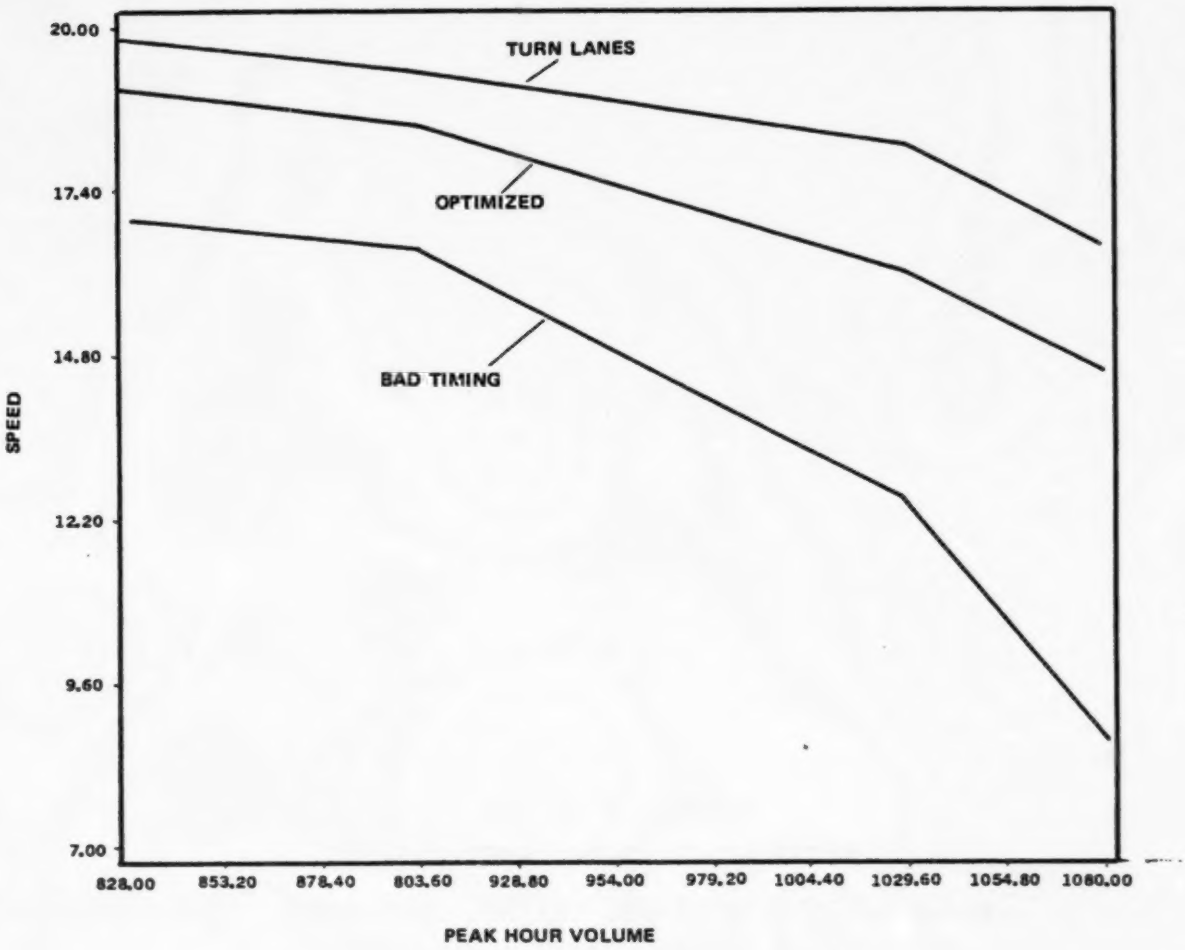


FIGURE 11

AVERAGE SPEED & PEAK HOUR VOLUME FOR THE THREE LEVELS OF INTERSECTION TRAFFIC FLOW IMPROVEMENT



STAPPA MODELING CONCERNING PROPOSED RELAXATION OF AUTOMOBILE CERTIFICATION STANDARDS

PRESENTED TO THE
NINTH ANNUAL NORTH AMERICAN
MOTOR VEHICLE EMISSIONS CONTROL CONFERENCE
BY DR. JAMES LENTS, DIRECTOR
AIR POLLUTION CONTROL DIVISION
COLORADO DEPARTMENT OF HEALTH

MAY 5-7, 1982

Introduction

At the present time the Congress is in the process of making decisions with respect to the Clean Air Act. One proposal under consideration is the relaxation of automobile certification standards. Since automobile emissions are a major contributor to air pollution in our major cities, the State and Territorial Air Pollution Program Administrators (STAPPA) initiated a program to evaluate the impact of one of the more prominent proposals to relax the automobile certification standards. The proposal reviewed was that offered in the original Traxler/Hillis Bill. Most of its proposed automobile relaxations, along with some further warranty and testing relaxations, were included in H.B. 5252 which is the prime House Bill under consideration at the present time. This paper discusses the STAPPA survey.

Before discussing the results of the STAPPA survey, it is useful to review the modeling process in order to set up an appropriate back drop to discuss the results of the survey.

The normal process in making projections of ambient data is to develop estimates of emissions data from various sources and to combine this with meteorological data to output projected ambient levels of a pollutant. Figure 1 illustrates this process. As can be seen this is no simple process.

Mobile Source Emissions

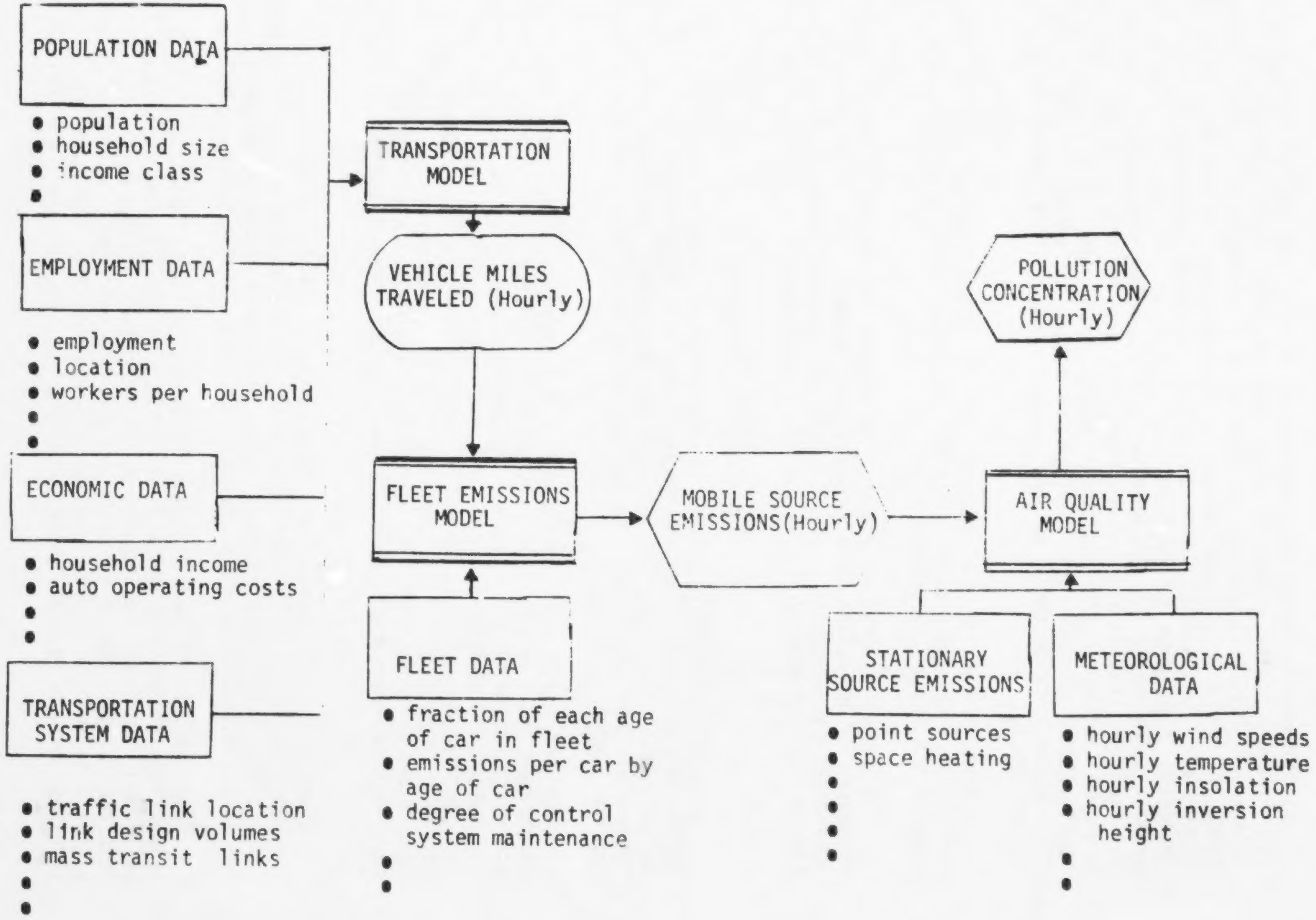
In order to estimate mobile source emission data, vehicle miles traveled (VMT), traffic speed, ambient temperature, and fleet distribution data must be developed in order to develop mobile source emission data. STAPPA recommended the use of the EPA mobile source model Mobile 2 as the "vehicle" for the STAPPA study.

For the base case modeling (i.e. present Clean Air Act), STAPPA recommended that Mobile 2 be used as is except for the emission factors for the micro-processor car. It was recommended that they be reduced slightly. The rational for this was the positive experience California has had with the micro-processor car and the more optimistic view provided by the National Commission on Air Quality for the micro-processor car. Also at that time we were receiving indications from EPA that they felt they may have been too pessimistic with respect to the micro-processor car in Mobile 2.

Subsequent to the more "optimistic" STAPPA projections for the micro-processor car, EPA came forward with a new set of emission factors for these cars essentially identical with the STAPPA recommendations except for the high altitude case where EPA was even more optimistic than STAPPA.

Although STAPPA had its own ideas as to the impact of the proposed relaxations on inuse automobile emissions, it was decided to contact EPA to get their input on the impact of the proposed relaxations. EPA was very helpful in supplying to us their thinking at the time. A review of the EPA suggestions by the STAPPA mobile source committee indicated that the EPA thinking concerning the appropriate emission factors for the relaxed case

FIGURE 1


POPULATION DATA
• population
• household size
• income class
•
EMPLOYMENT DATA
• employment
• location
• workers per household
•
•
ECONOMIC DATA
• household income
• auto operating costs
•
•
TRANSPORTATION SYSTEM DATA
• traffic link location
• link design volumes
• mass transit links
•
•
TRANSPORTATION MODEL
VEHICLE MILES TRAVELED (Hourly)
FLEET EMISSIONS MODEL
FLEET DATA
• fraction of each age of car in fleet
• emissions per car by age of car
• degree of control system maintenance
•
•
MOBILE SOURCE EMISSIONS(Hourly)
AIR QUALITY MODEL
POLLUTION CONCENTRATION (Hourly)
STATIONARY SOURCE EMISSIONS
• point sources
• space heating
•
•
•
•
METEOROLOGICAL DATA
• hourly wind speeds
• hourly temperature
• hourly insolation
• hourly inversion height
•
•

was essentially the same as ours. We thus recommended the use of these emission factors for studying the effect of the proposed relaxations. Figure 2 shows the emission factors used along with those suggested by other sources.

With respect to the other important variables that effect mobile source emissions (i.e. vehicle miles traveled, ambient temperatures, traffic speeds, model distribution, etc.) we asked that the states use the best local data available. We believe that the state and local groups are best able to develop this data.

Stationary Source Data

In the case of stationary source data, we asked that the states use the data they had developed within their normal emission inventory. All states maintain records on all major sources and most states maintain records with respect to small sources and area sources.

Air Quality Model

No requirements were made with respect to what ambient models were to be used. Most states used Linear Rollback as is the case for most industry and EPA projections. Colorado was an exception in that the SAI "Urban Air Shed" model was used for carbon monoxide projections. In reality a comparison betwen the "Urban Air Shed" model and equivalent rollback modeling showed no significant differences.

Calibration of the Model

In order to have confidence that a model is reasonable, it is normally run for an existing situation to see how well the predicted results compare with the actual measured data. Figures 3-14 illustrate simplified comparisons for several cities around the nation. Shown on each figure is a line corresponding to a rollback projection using Mobile 2 for the case of no VMT growth and for the case of 4% per year VMT growth. Also a least square fit line is shown on each graph for the measured winter means for the respective stations. Actual data points are also shown.

As can be seen the least square fit line falls very near or between the no growth and 4% annual growth lines with one exception. This exception is a commercial site in Albuquerque where ambient levels are falling noticably faster than the no growth line. It could be that the 1976 data point represents an error. The data for this winter appears suspect relative to the other Albuquerque data. If this data point is dropped then a very reasonable projection is realized as can be seen in Figure 9a. It appears that Mobile 2 is making reasonable projections relative to actual CO data.

Another area of potential correlation that was examined for Colorado was to compare CO ambient readings to NO_x ambient readings. Since automobiles are expected to account for most of the CO and NO_x production at center city sites in Colorado, a strong CO to NO_x correlation was expected. The ratio of CO to NO_x can be predicted from Mobile 2 offering another means to check Mobile 2. Appendix A gives a description of the study. The key result is that CO and NO_x correlate well and about in the ratio predicted by Mobile 2.

FIGURE 2

CARBON MONOXIDE EMISSION FACTORS FOR IN USE LIGHT-DUTY VEHICLES (NO I/M PROGRAM)

LOW ALTITUDE

Certification Standard		EPA Mobile 2	EPA Report to Congress	NCAQ	NCAC	STAPPA
3.4 gm/VMT CO and 1.0 gm/VMT NO_x	Zero mile Emissions	5.00	3.21	3.84	-	3.26
	Deterioration per 10K miles	2.76	1.88	2.99	-	1.83
	Emissions at 50K miles	18.80	12.61	18.79	-	12.41
7.0 gm/VMT CO and 2.0 gm/VMT NO_x	Zero mile Emissions	6.14	3.58	6.97	4.32	4.47
	Deterioration per 10K miles	2.86	1.92	1.99	4.05	2.08
	Emission at 50K miles	20.44	13.18	16.92	24.57	14.87
HIGH ALTITUDE						
3.4 gm/VMT CO and 1.0 gm/VMT NO_x	Zero mile Emissions	7.18	3.75	3.84	-	4.23
	Deterioration per 10K miles	4.22	2.24	2.99	-	2.40
	Emissions at 50K miles	28.28	14.95	18.79	-	16.23
11.0 gm/VMT CO and 2.0 gm/VMT NO_x	Zero mile Emissions	19.5*	5.63	-	-	10.8
	Deterioration per 10K miles	2.86	1.92	-	-	2.20
	Emissions at 50K miles	33.80**	15.23	-	-	21.8

* This is for the 1977 High-altitude car built to a 15 gm/VMT CO certification standard

** If the zero emission rate is proportioned down for an 11/gm/VMT car, then the 50K emissions would be 28.6 gm/VMT

FIGURE 3

ATLANTA WINTER MEANS
FIRE STATION #15

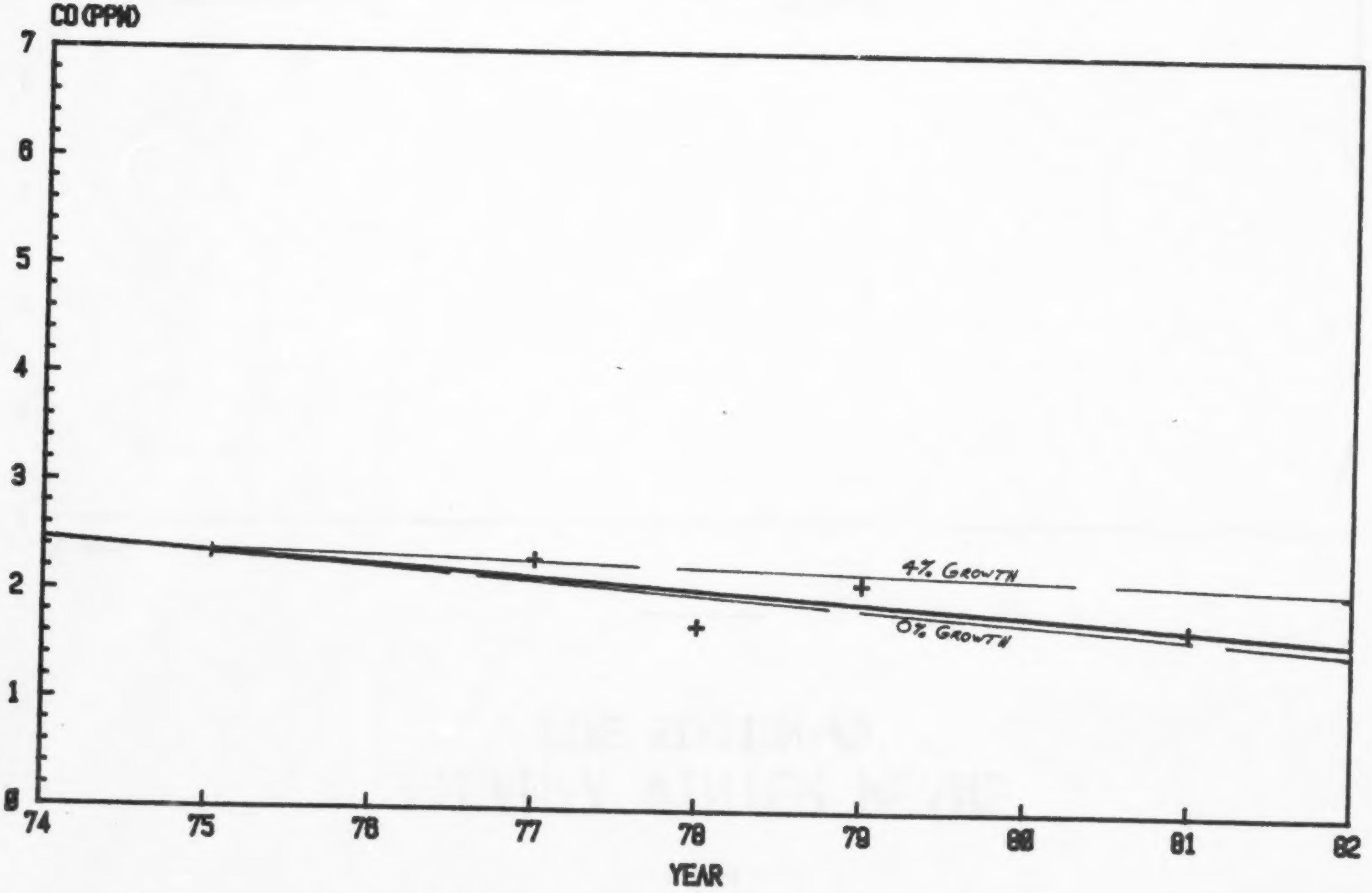


FIGURE 4

ATLANTA WINTER MEANS
FIRE STATION #5

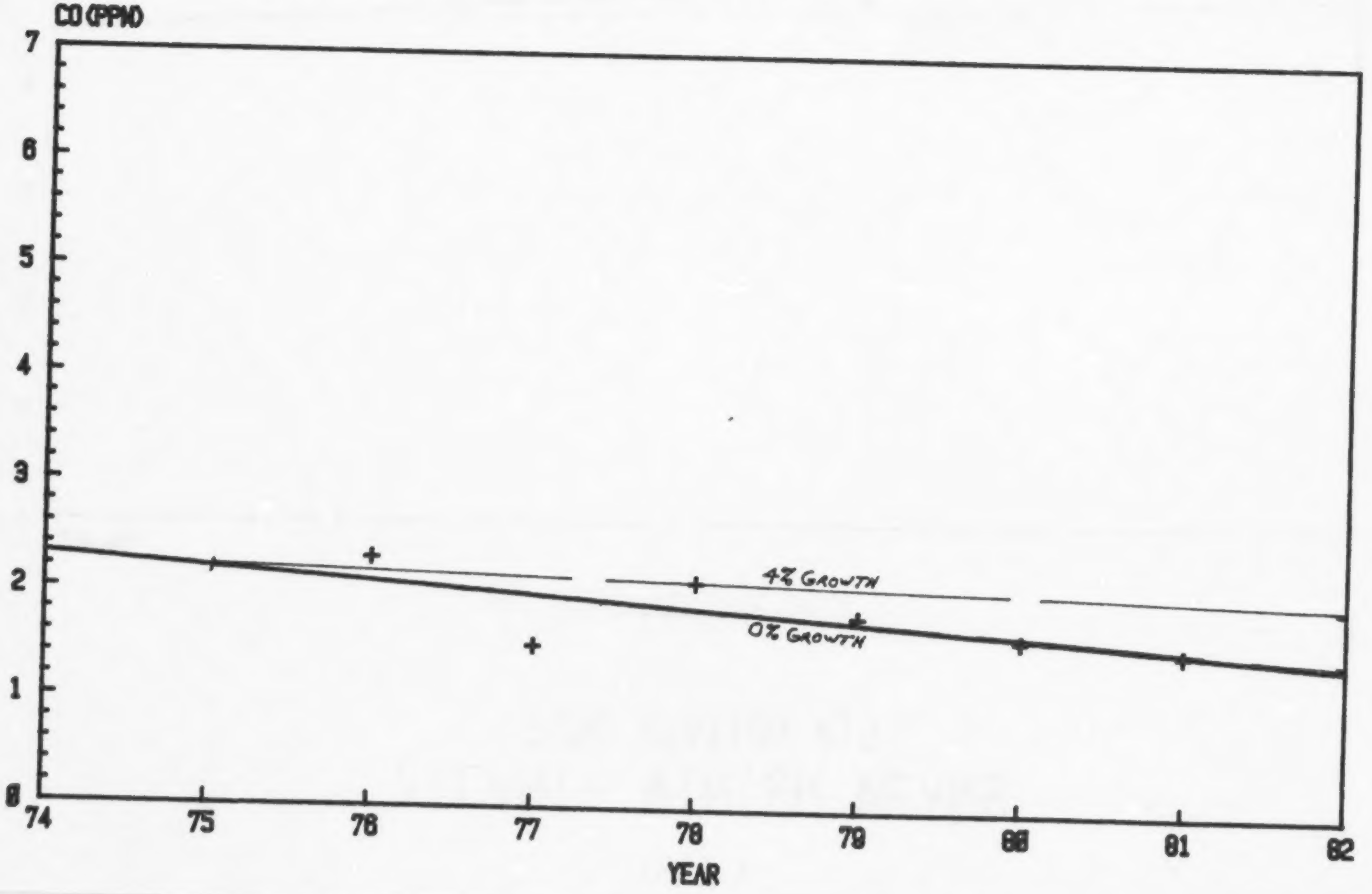


FIGURE 5

CHICAGO WINTER MEANS
LOOP STATION

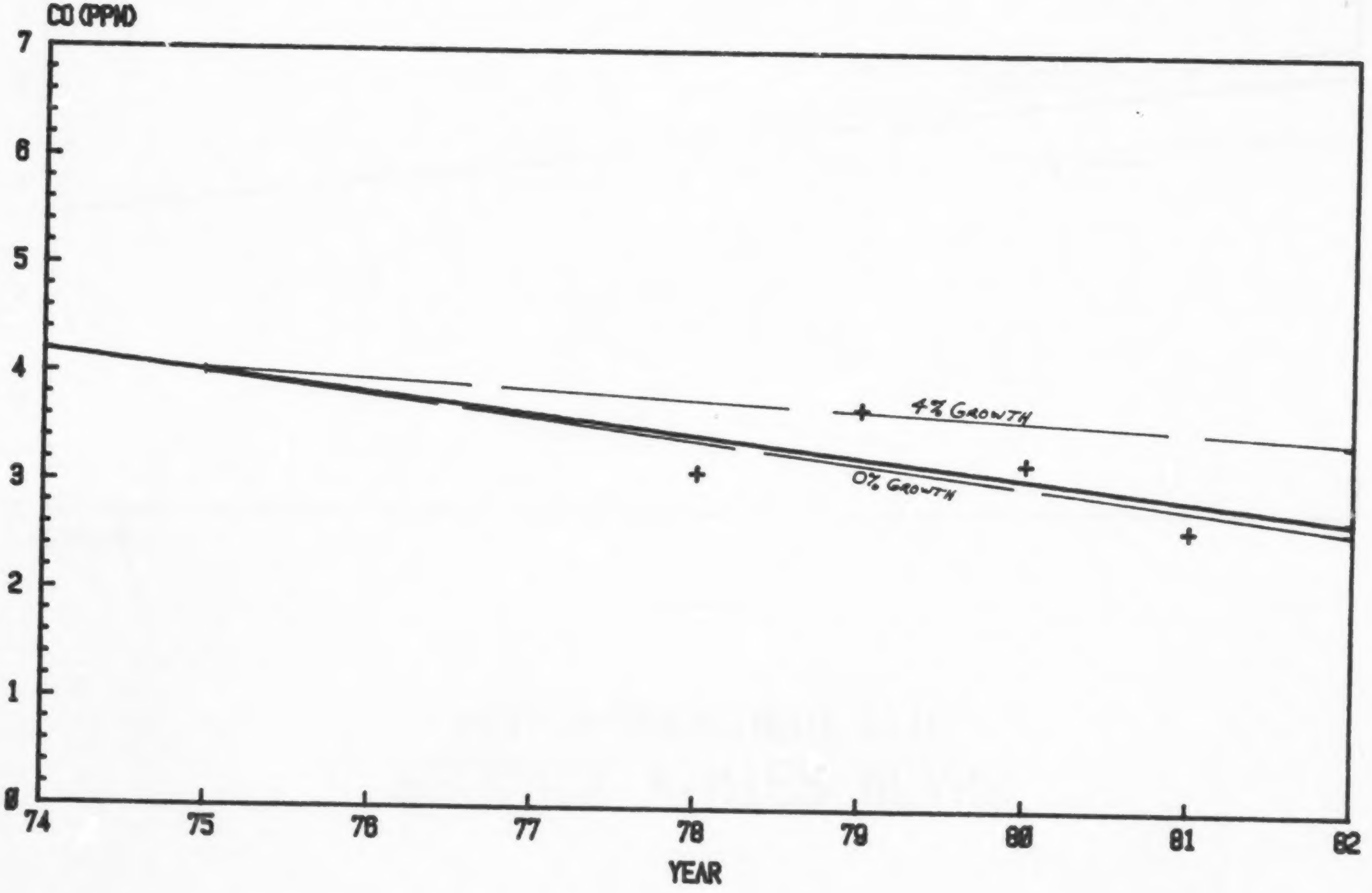


FIGURE 6

PHOENIX WINTER MEANS
HEALTH DEPARTMENT SITE

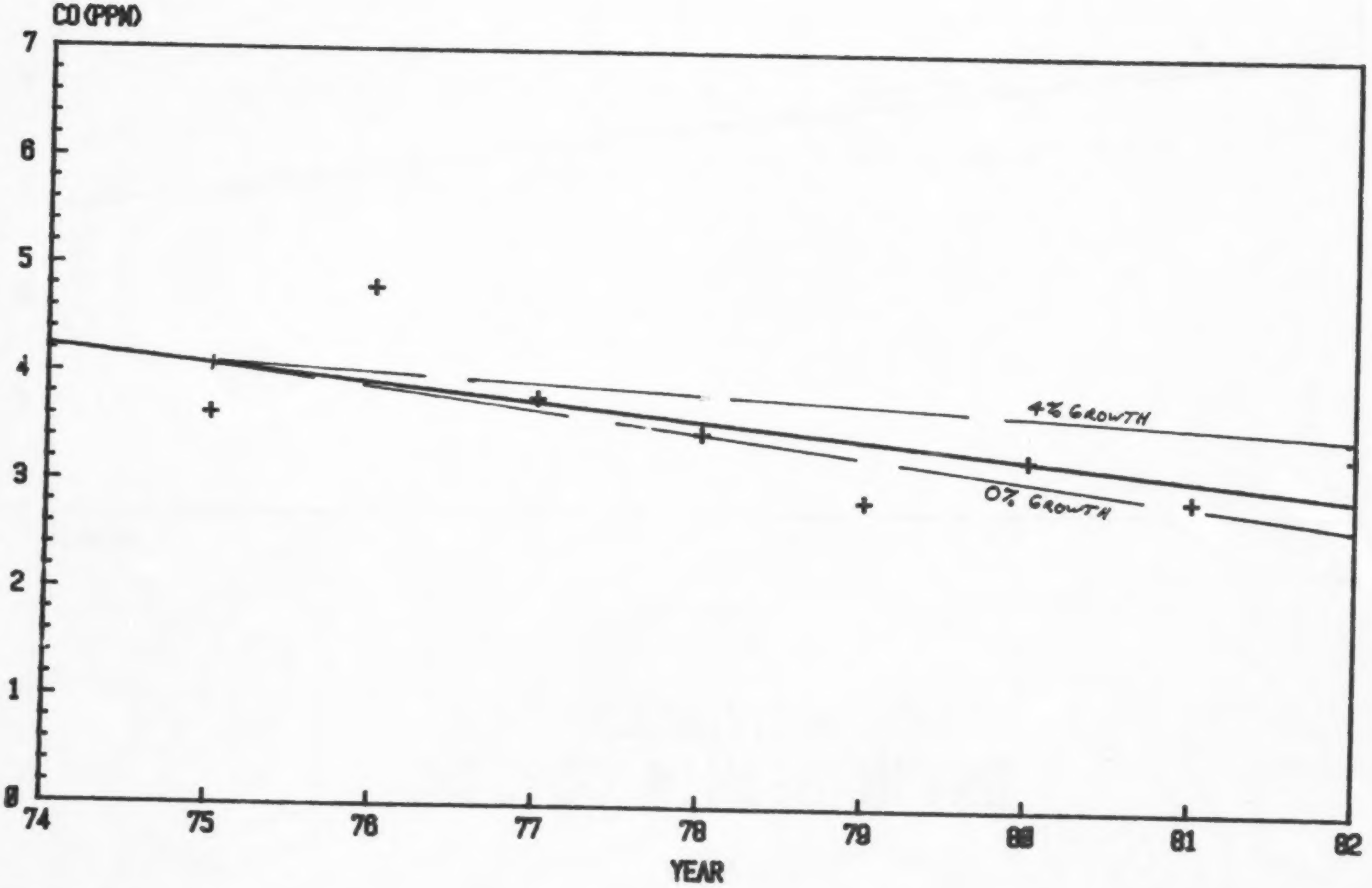


FIGURE 7

PHOENIX WINTER MEANS
SCOTTSDALE SITE

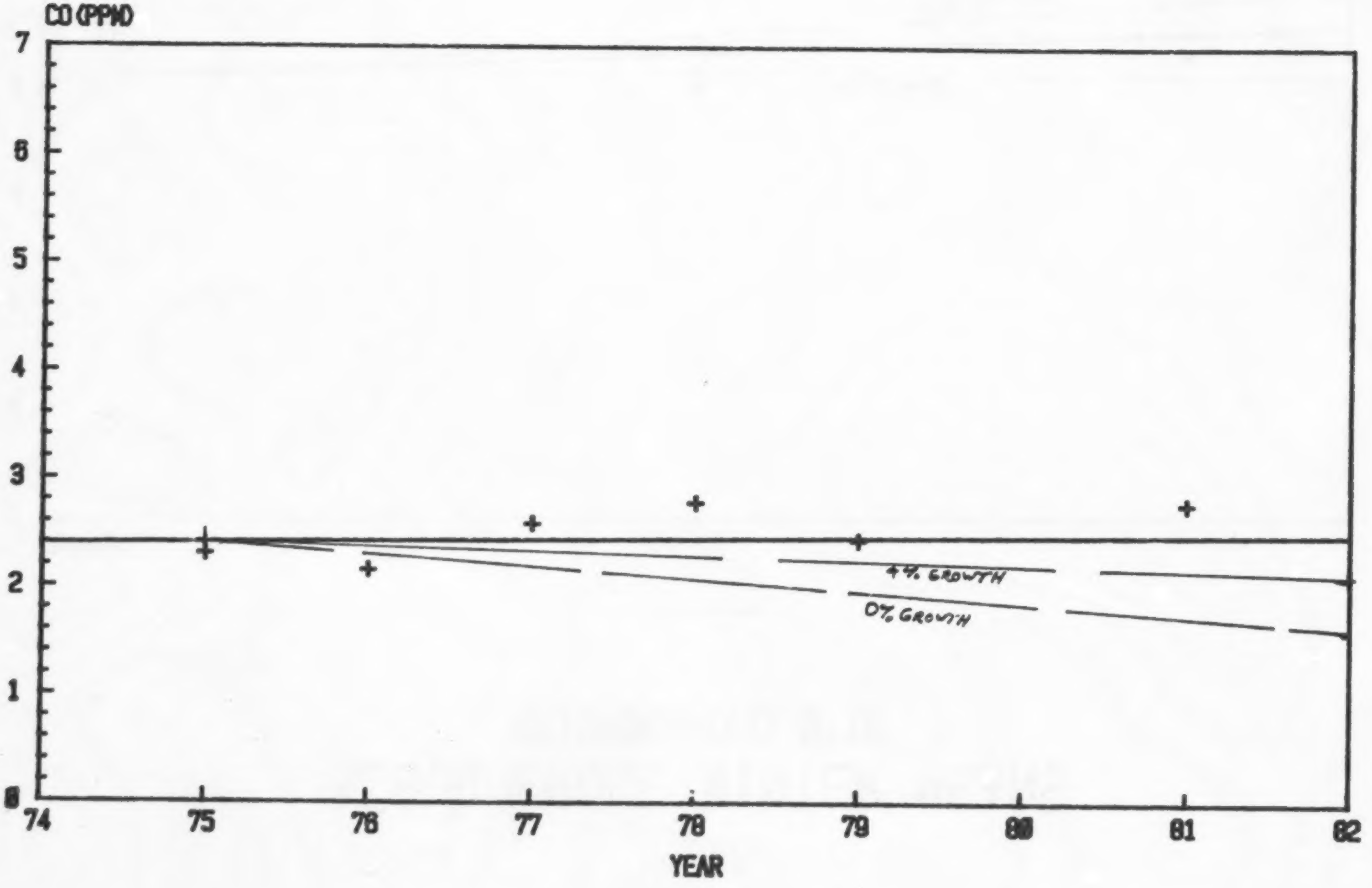


FIGURE 8

ALBUQUERQUE WINTER MEANS
NEIGHBORHOOD SITE

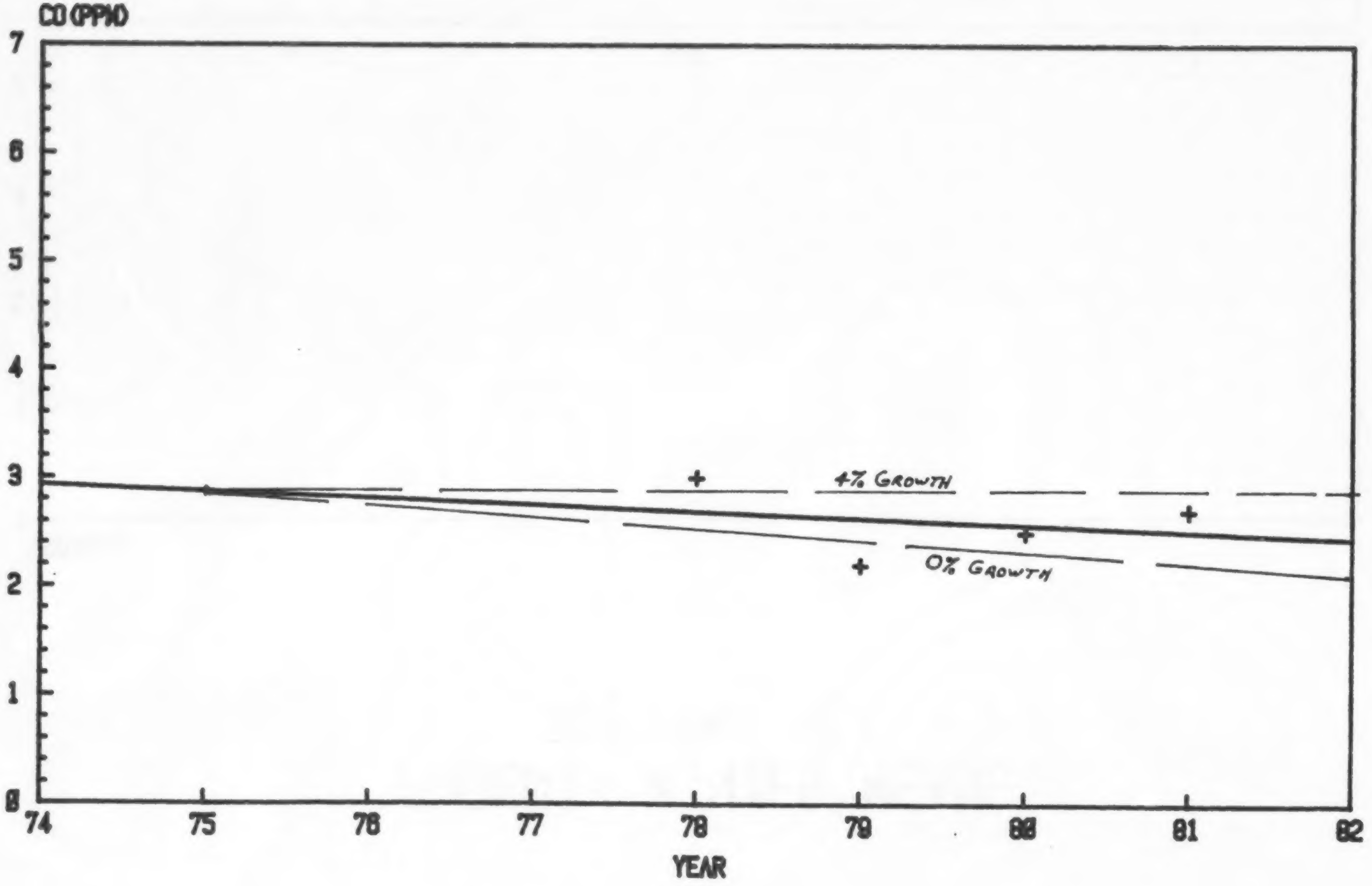


FIGURE 9

ALBUQUERQUE WINTER MEANS
COMMERCIAL SITE

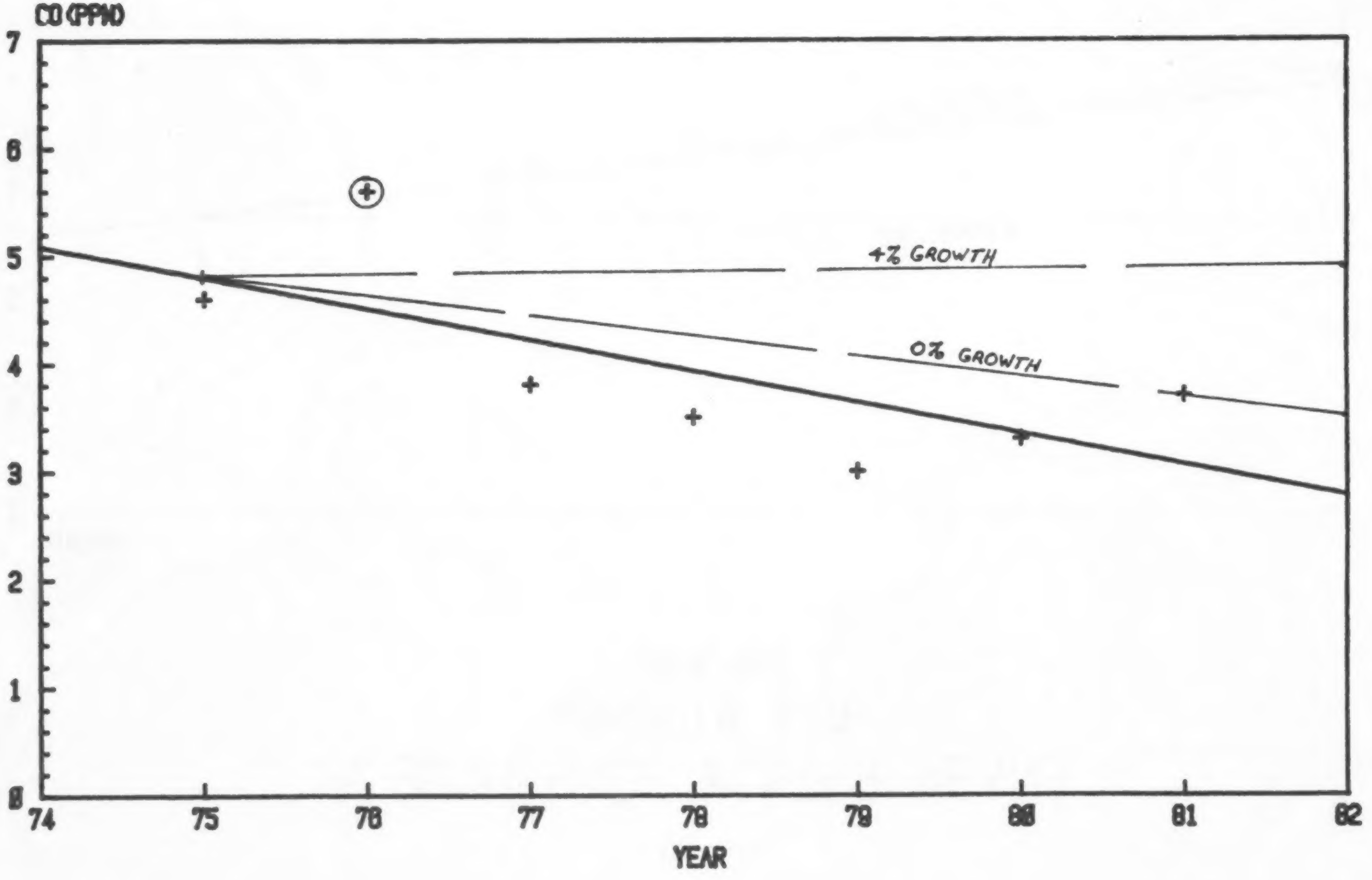


FIGURE 9a

ALBUGUERQUE WINTER MEANS
COMMERCIAL SITE
LINEAR FIT

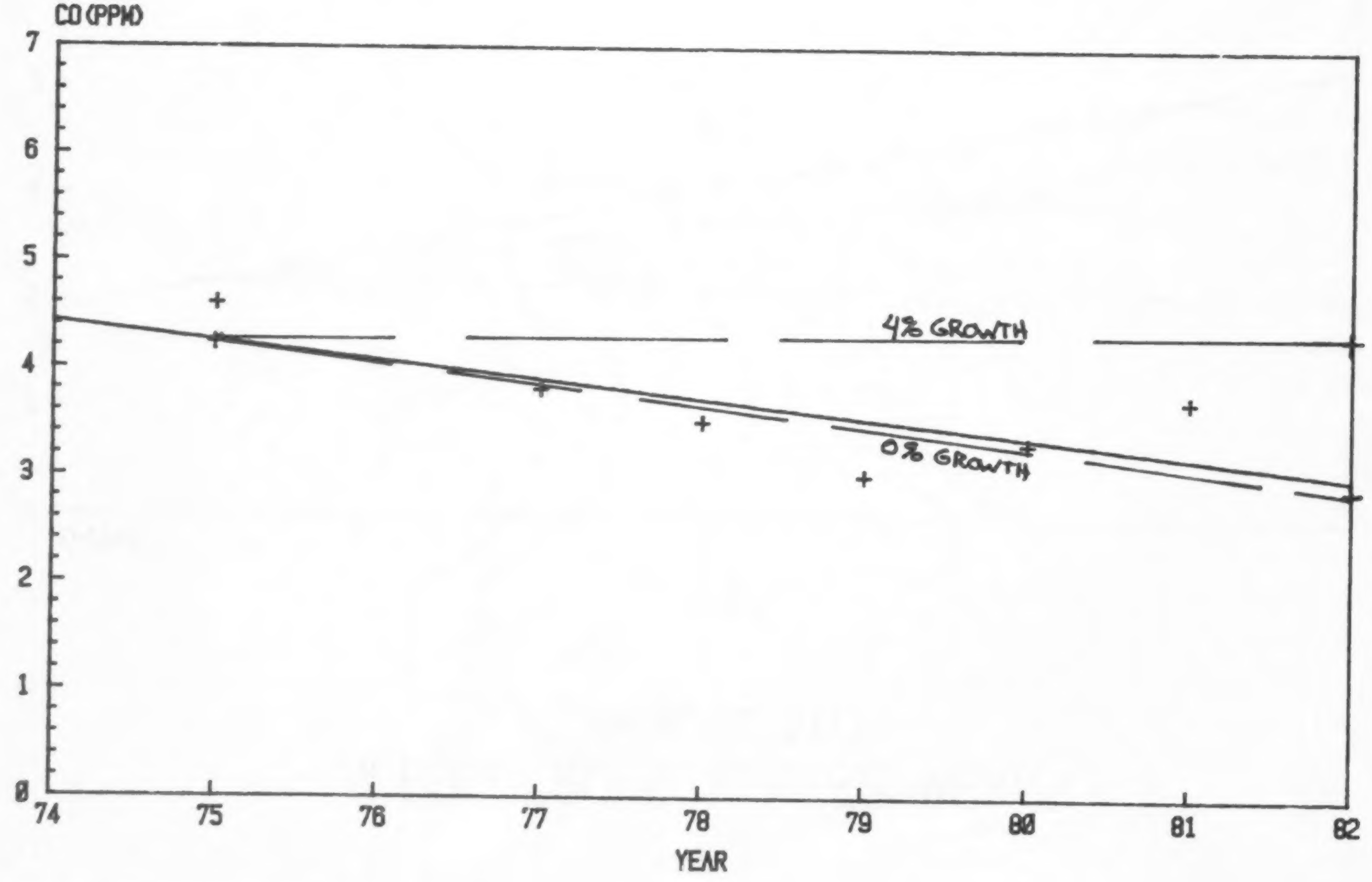


FIGURE 10

ALBUQUERQUE WINTER MEANS
DOWNTOWN STATION

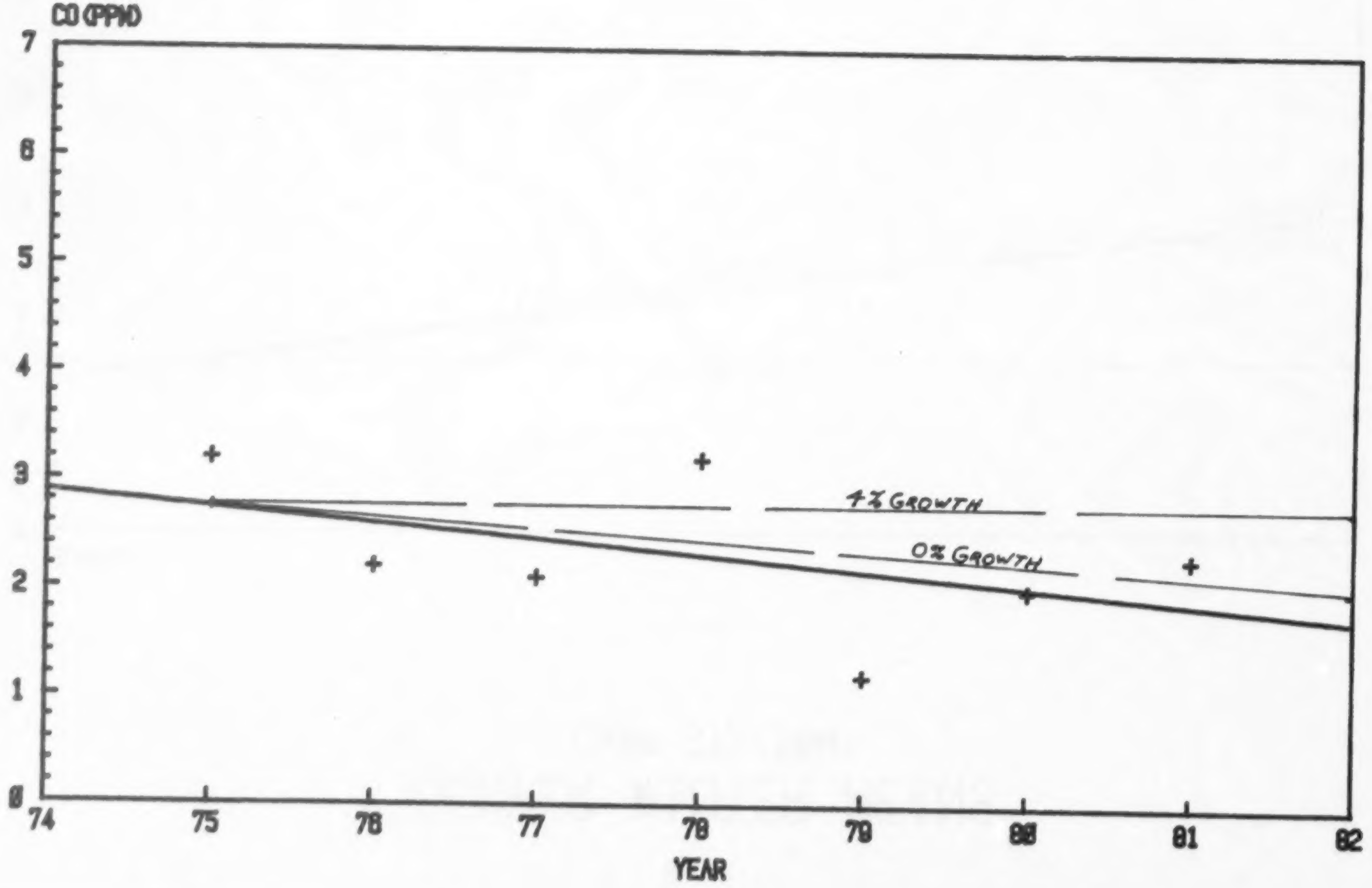


FIGURE 11

DENVER WINTER MEANS
CAMP STATION

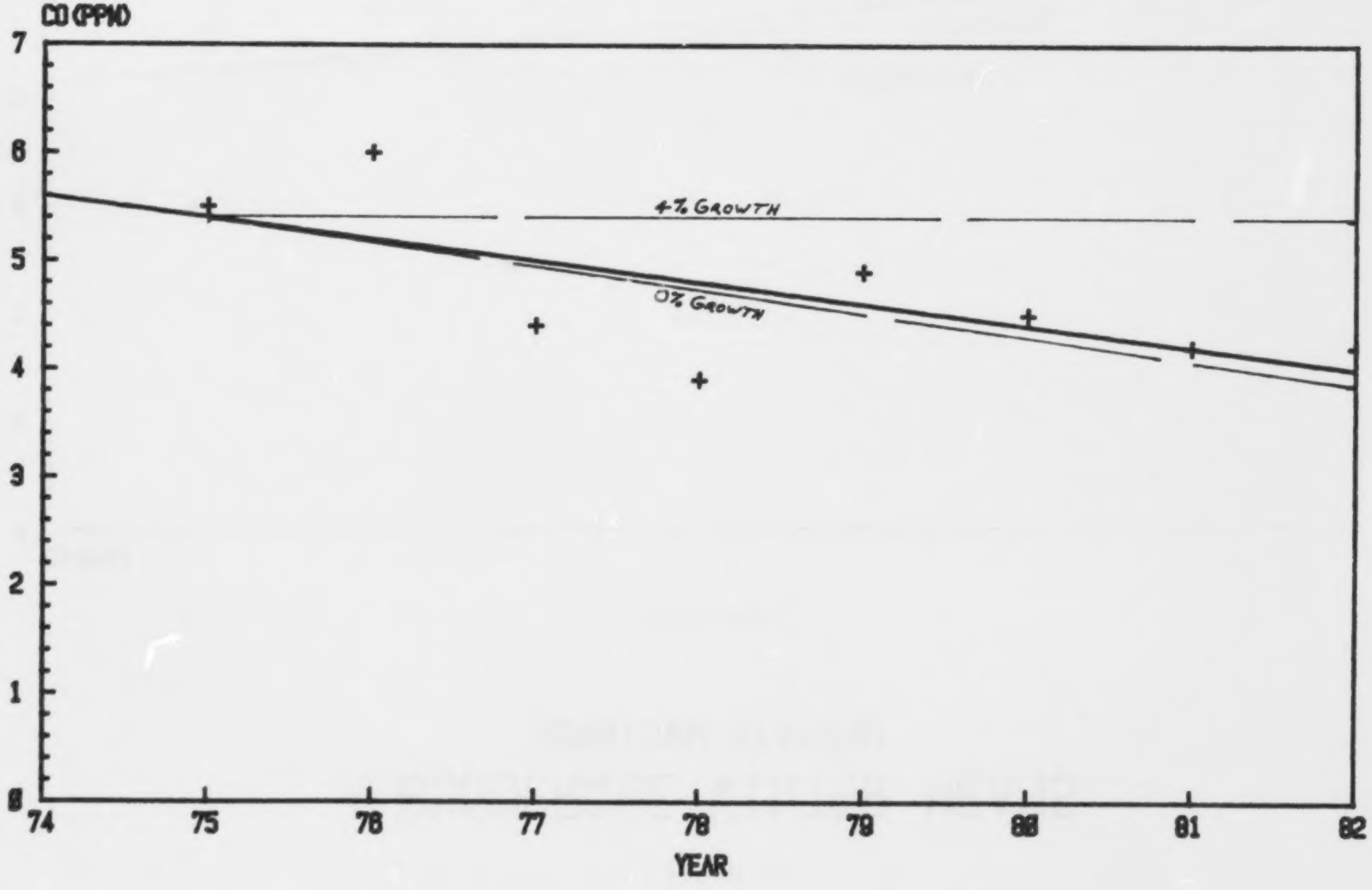


FIGURE 12

DENVER WINTER MEANS
CARIH STATION

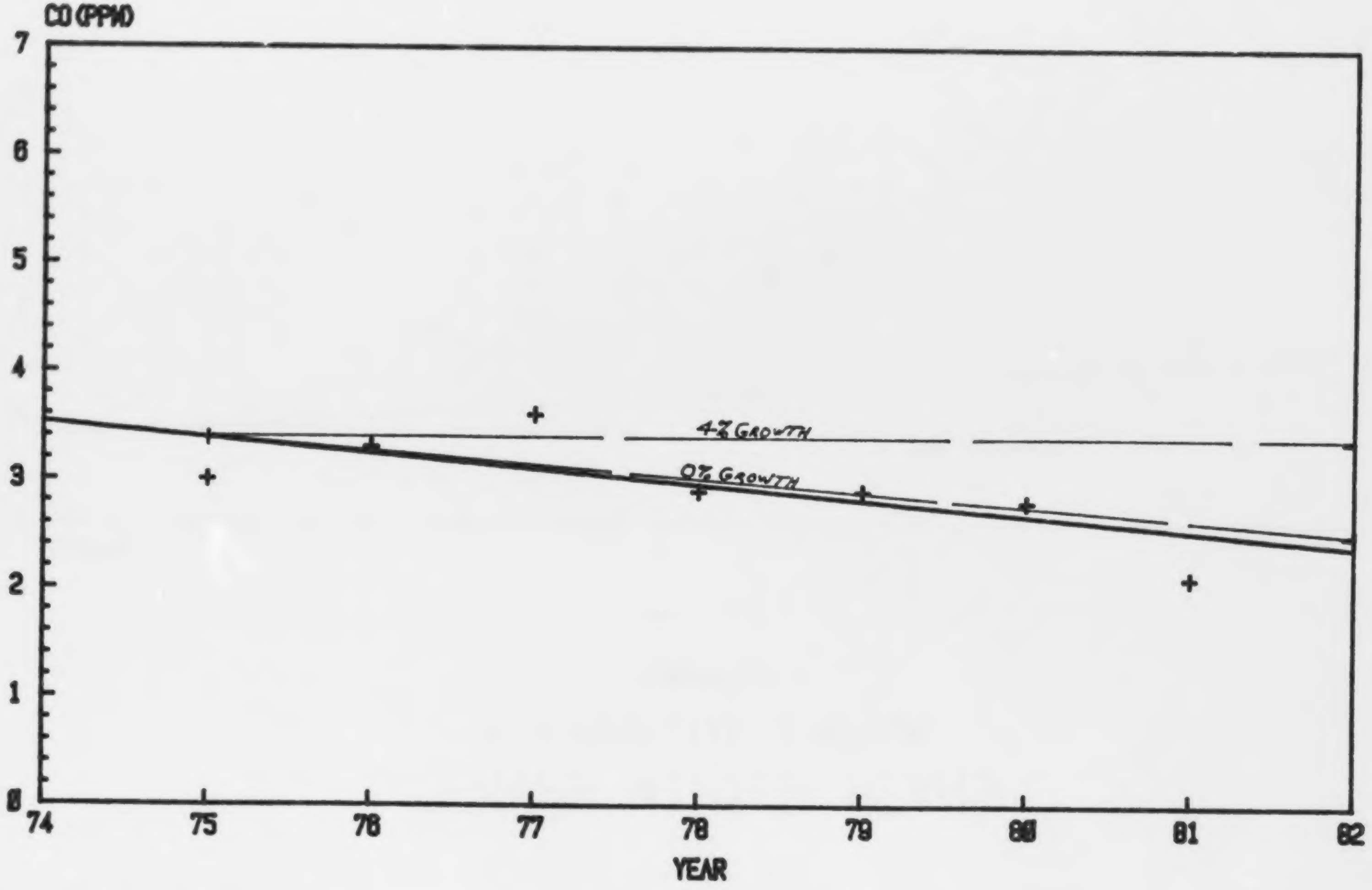


FIGURE 13

DENVER WINTER MEANS
NJH HOSPITAL STATION

LINEAR FIT

———

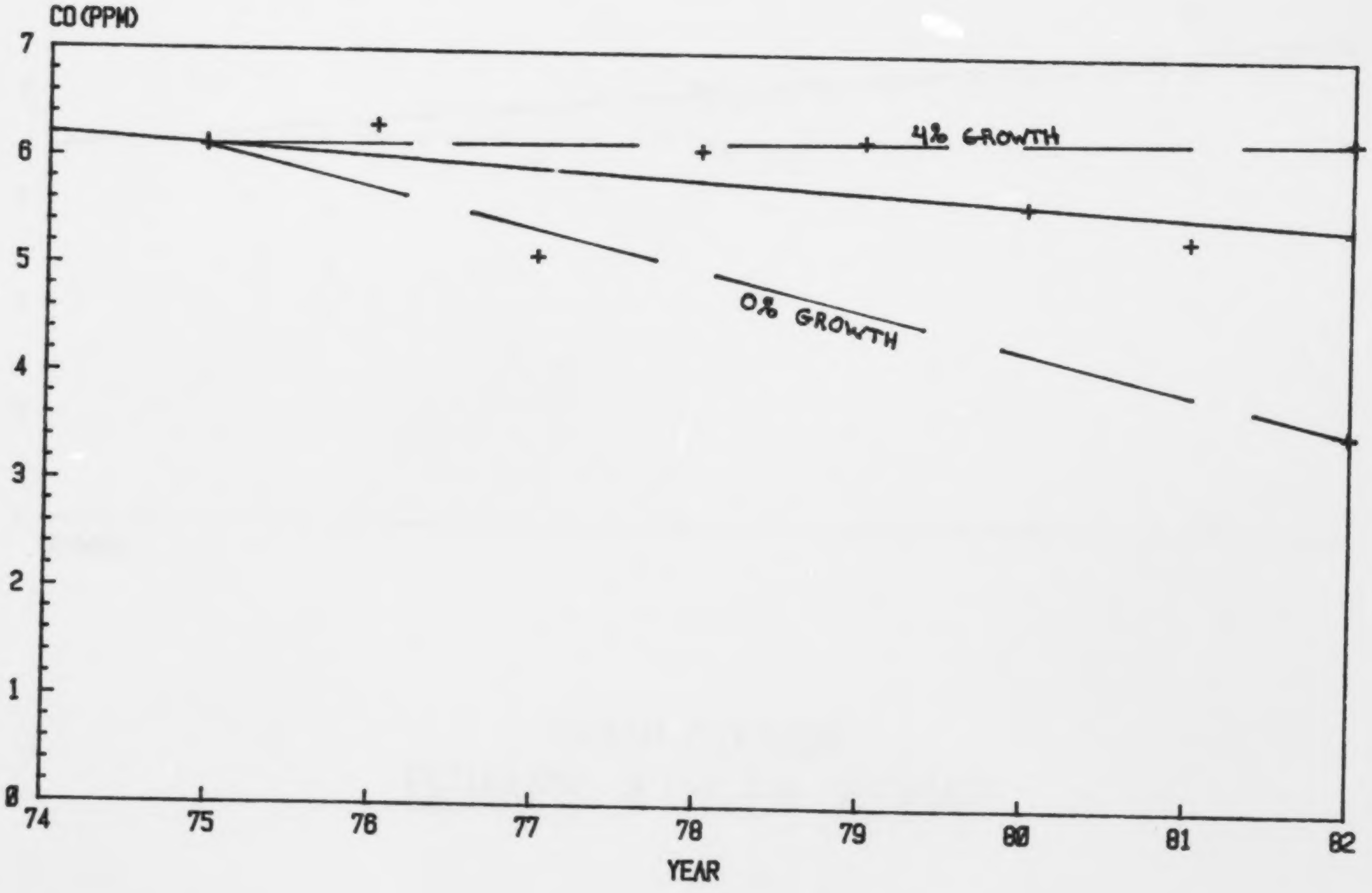
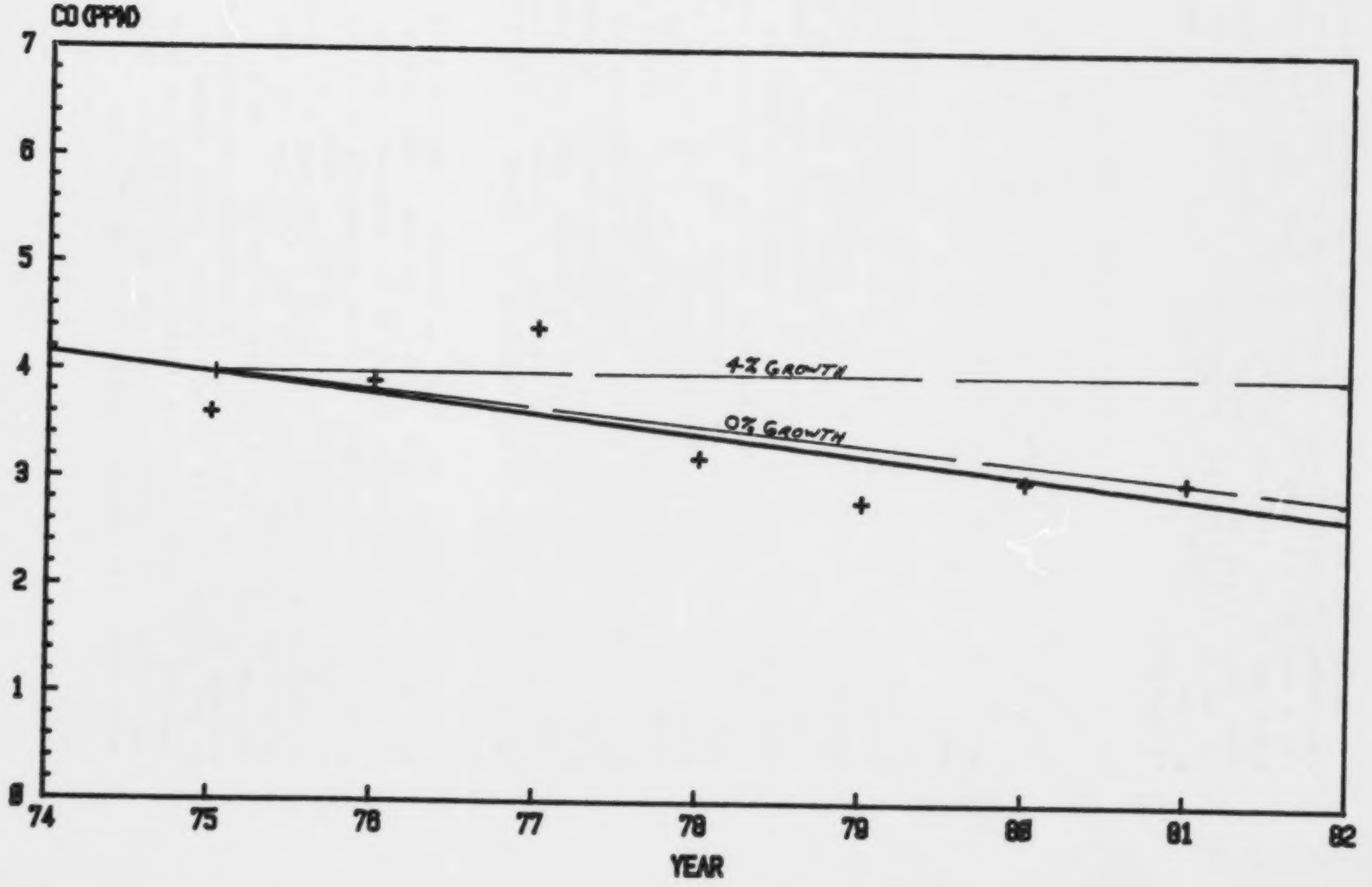


FIGURE 14

SALT LAKE CITY WINTER MEANS

NEIGHBORHOOD SITE



Actual Results from STAPPA Survey

Tables 15, 16 and 17, were taken from Governor Rockefeller's testimony concerning proposed changes to the Clean Air Act. As can be seen in Table 15, a significant negative potential impact was found for 36 metropolitan areas due to the proposed relaxations for carbon monoxide. Tables 16 and 17 show those areas most effected by the proposed NO_x relaxations. Figures 18 and 19 illustrate NO_x projections for the Denver CAMP station. As can be seen a significant NO_2 impact could occur in Denver due to the relaxations.

Criticisms of the Projections

The two areas where there has been the most criticism of the projections is with respect to projected VMT growth rates and projected auto emission factors. As was shown earlier the emission factors used were very much within the range of values suggested by other studies. They can be easily supported from actual historical data.

Some observers argue that state and local governments tend to over project future VMT growth rates. This is based on the observation that VMT growth rates through the 70's were generally low as illustrated indirectly in Figures 3-14. It is quite possible that the 70's were the exception rather than the rule. This is discussed later. Population has been increasing at a rate of 1%. It is expected to continue at this rate over the next 10-15 years. If each area received an average share of this growth then there would be an average growth rate of about 1%. However, this growth will not happen equally everywhere. Some areas will grow faster than others so that much higher growth rates will be observed at some locations and negative growth will be observed elsewhere. Critics however argue that this growth will occur in the suburbs of cities not in the central areas where CO readings are high. In response to this it should be noted that many cities are reworking their downtowns with full community support in order to attract more people downtown. In Denver for example, enough office space is being added in the downtown to support a 2-3% per year growth rate for the next 10 years.

A final question that might be raised is why has some of this growth not been as observable in the 1970's. In many cases growth has been observed. In Denver the 1970's VMT growth in the downtown area was low. This low VMT growth was likely caused by a brief carpooling effort by the public. Fuel shortages and escalating fuel prices caused a temporary attempt at carpooling by the public. Figure 20 illustrates this point. As can be seen carpooling increased between 1971 and 1979 but has been decreasing since. The magnitude of the carpooling in Denver is adequate to mask an annual average VMT growth rate of 2%. If carpooling steadies out or decreases then a VMT growth rate of 2% or greater could redevelop. If other cities incurred the same temporary increase in carpooling then it is likely that low 1970s' VMT growth rates are an anomoly. Recent gasoline price relaxations will further support increased VMT.

Table 15

Areas Projecting More Than One Year Delay in Attainment for Carbon Monoxide[a]

Area	Delay
1. Fairbanks, Alsaska	Indefinite beyond 2000
2. Phoenix, Arizona Indefinite beyond 2000	
3. San Diego County, California[b]	Cannot project ever reaching attainment
4. San Francisco Bay Area, California[b]	Cannot project ever reaching attainment
5. Sacramento County, California[b]	Cannot project ever reaching attainment
6. Ventura County, California[c]	Cannot project ever reaching attainment
7. Santa Barbara County, California[c]	Cannot project ever reaching attainment
8. Stanislaus County, California[c]	Cannot project ever reaching attainment
9. San Joaquin County, California[c]	Cannot project ever reaching attainment
10. Kern County, California[c]	Cannot project ever reaching attainment
11. Lake Tahoe Air Basin, California[b]	Cannot project ever reaching attainment
12. South Coast Air Basin, California[b]	Cannot project ever reaching attainment
13. Fresno County, California[b]	Cannot project ever reaching attainment
14. Denver, Colorado[b]	Cannot project ever reaching attainment
15. Fort Collins, Colorado[b]	1-2 years
16. Atlanta, Georgia[b]	3 years
17. Chicago, Illinois	3 years
18. Jefferson County, Kentucky[d]	1-3 years
19. Boone County, Kentucky[d]	1-3 years
20. Kenton County, Kentucky[d]	1-3 years
21. Campbell County, Kentucky[d]	1-3 years
22. Massachusetts,[b,e]	2-4 years
23. St. Louis, Missouri[b]	1 years
24. Nashua, New Hampshire	1-2 years
25. Morristown, New Jersey[b]	2 years
26. Albuquerque, New Mexico[b]	10-13 years
27. Mecklenburg County, North Carolina[b]	2-3 years
28. Tulsa County, Oklahoma	1 year
29. Portland, Oregon[b]	1 year
30. Eugene, Oregon	1 year
31. Medford, Oregon[b]	1+ years
32. Provo, Utah	13 months
33. Salt Lake City, Utah[b]	23 months
34. Chittenden County, Vermont	24-30 months
35. Washington, D.C.[f]	----
36. Bellevue, Washington[g]	15 years
37. Seattle, Washington[g]	3 years
38. Takoma, Washington[g]	9½ years

Ten states reported presently having no nonattainment areas for carbon monoxide or projected attainment by 1982 for existing nonattainment areas.

Six states which currently have carbon monoxide nonattainment areas reported delays less than six months (Indiana, Kansas, Michigan, Texas, Virginia, and Wisconsin).

Six states did not analyze this question in their responses.

Table 16

New Nonattainment Areas Which May be Created As a Result of Relaxations[a]

Carbon Monoxide

1. Ventura County, California
2. Grand Junction, Colorado
3. Jackson, Mississippi
4. Chittenden County, Vermont

Nitrogen Oxide

1. Kern County, California
2. San Diego County, California
3. Chicago, Illinois[b]
4. Boston, Massachusetts
5. Pioneer Valley, Massachusetts
6. Providence, Rhode Island
7. Washington, D.C.
8. Southeastern, Wisconsin

---

[a] Under Scenario IV

[b] Projected to reach attainment by 1984 under base case but delayed beyond 198~~[illegible]~~ 7 under Scenario IV

Table 17

Areas Currently in Attainment Which May Have To Require Additional "Reasonably Available Control Technology" (RACT) To Avoid Becoming Nonattainment

1. Kern County, California
2. San Diego County, California
3. Boston, Massachusetts
4. Pioneer Valley, Massachusetts
5. St. Louis, Missouri[a]
6. North Carolina (1 site unnamed)
7. Philadelphia, Pennsylvania
8. Washington, D.C.
9. Southeastern AQCR, Wisconsin
10. Casper, Wyoming
11. Rock Springs, Wyoming

Existing Nonattainment Areas Experiencing Further Delays in Reaching Attainment for NO_2 Which Would Require Additional RACT

1. Chicago, Illinois
2. Denver, Colorado
3. Los Angeles, California

12 states did not analyze this issue

16 states reported no potential problems

[a] indicated positive need for additional controls on area source

FIGURE 18

NO_2 Projections for Denver

Assume 10% NO_2 is stationary

Assume 2% per year stationary source growth

Assume 1% per year VMT growth

	YEAR	RELATIVE NO_2 EMISSIONS
BASE CASE	1979	1.0
	1987	.87
	1990	.81
	1995	.76
	2000	.78
RELAXED CASE	1979	1.0
	1987	1.04
	1990	1.07
	1995	1.12
	2000	1.17

FIGURE 19

PROJECTION OF AMBIENT NO_2 LEVELS

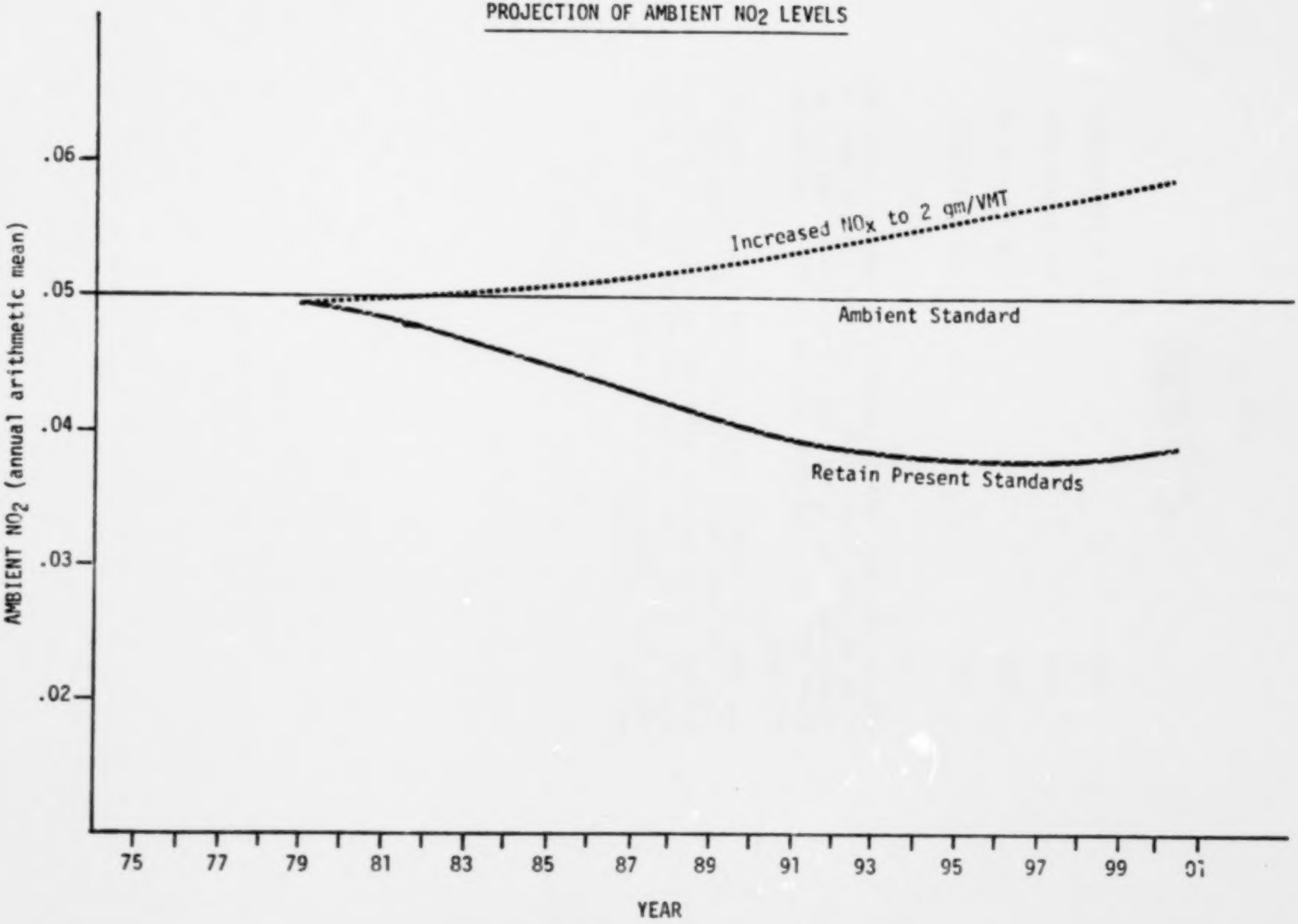


FIGURE 20

DENVER AVERAGE PER CAR RIDERSHIP

1971	1.15 Persons/Car
1979	1.32 Persons/Car
1980	1.28 Persons/Car
1981	1.23 Persons/Car

Between 1971 and 1979 an increase of downtown employment of 2% per year would yield an apparent .2% per year VMT growth rate. Add to this the increased bus ridership and there will be no apparent increase in VMT or an apparent decrease.

Now that the shock of gasoline prices is wearing off, and cars are more fuel efficient, per car ridership is falling. Coupling this with the saturation of the mass transit system leads to the expectation that VMT growth rates will return to a value directly associated with employment growth rates.

Conclusions

It is our conclusion that the STAPPA study is a realistic indicator of what would likely happen to ambient CO and NO_2 levels in a number of locations around the nation if automobile certification standards are relaxed. STAPPA's concern over the relaxations of automobile certification standards is thus well founded.

APPENDIX A

Correlations Between Carbon Monoxide Levels and Nitrogen Oxide Levels in Downtown Denver and Colorado Springs

Current issues of debate concerning the amendments to the Clean Air Act have led to the analysis of various pollutant levels in major U.S. cities. One of the pollutants of concern is nitrogen dioxide.

It has been argued by some researchers that center city nitrogen dioxide concentrations should, or by other researchers, should not relate to the same air pollution sources as carbon monoxide. In Denver, about 90% of the carbon monoxide problem is associated with direct automotive tailpipe emissions. It would be logical to conclude that if automobiles were also a major contributor to the nitrogen dioxide problem a high degree of correlation would exist between ambient carbon monoxide and oxides of nitrogen levels. To briefly examine this hypothesis, ambient air data was examined from the Denver CAMP station located in central downtown Denver and at the South Tejon Colorado Springs station.

Three months of winter carbon monoxide, nitrogen dioxide, and nitric oxide data were examined. Daily mean levels and the maximum one-hour concentration for each pollutant were compared. Additions of daily mean NO and NO_2 levels were performed to create a data set which would represent total oxides of nitrogen.

Figure 1-3 depict the linear plot of the carbon monoxide and oxides of nitrogen analyzed from three different scenarios in Denver.

Figure 1 clearly demonstrates a linear relationship between average NO_x values and average CO levels on a daily basis. The coefficient of determination indicates that 77.9% of the variation of the CO daily mean can be explained by the variation in the NO_x daily mean. The correlation coefficient of .883 indicates a strong relationship between CO and NO_x daily means.

Figures 2 and 3 show the maximum one-hour CO and either NO or NO_2 values on a given day. A lower correlation exists due to complicating factors. Nitrogen dioxide is primarily produced photochemically resulting in the lower correlation but may be lower due to differences in peaking time of CO and NO under cold start conditions (typically most one-hour max CO values occur during late afternoon hours where NO values appear to have more evenly distributed morning/evening peaks).

It is significant to note that all three cases predice near zero intercepts when carbon monoxide approaches zero concentration. This further emphasizes the observation that a high degree of relationship exists between the sources of CO and NO_x in Denver.

Figures 4 - 6 present the same analysis for Colorado Springs. In these cases all correlations were statistically significant. This indicates even less contribution from non carbon monoxide-related sources. It is of interest to note the change in the linear equation relating NO_x and CO from the Denver case. Two high NO_2 but low CO values in Figure 4 impact the linear fit. These values may be caused by a local power plant. Figure 7 is the same as Figure 4 with the two points removed. The difference between the slopes for the Denver data and the Colorado Springs data may be due to the difference in altitude, automobile maintenance, or fleet mix near the stations.

Table I illustrates a theoretical calculation which uses EPA Mobile II data to estimate the relative number of CO molecules being emitted by mobile sources compared to the number of NO_x molecules being emitted. This calculation indicates that in a case where all CO and all NO_x is being generated by automobiles that the ambient PPM ratio of CO to NO_x should be on the order of 32. This calculation ignores any atmospheric reactions that might reduce the amount of CO or NO_x. As can be seen from Figures 1, 4 and 7 the measured Denver ratio is 33 and the measured Colorado Springs ratio is 20.

It is concluded that both cases show a high degree of relationship between NO_x ambient levels and CO levels. Both the Colorado Springs and Denver data imply a commonality of the major portion of the NO_x sources and CO sources.

TABLE I

Estimate of the Number of CO Molecules Compared to the Number of NO_x Molecules Being Generated by Mobile Sources Operated at Altitude

Fleet Average CO Emission Rate (1981)* = 103 gms/VMT

Fleet Average NO_x Emission Rate (1981)* = 3.74 gms/VMT

Molecular Weight CO = 28
Moleculate Weight NO = 30
Molecular Weight NO_2 = 46
90% NO + 10% NO_2 Molecular Weight = 32
Number CO Molecules $\frac{103}{28}$ = 3.68

Number NO_x Molecules $\frac{3.74}{32}$ = .117

$\frac{\text{Number CO Molecules}}{\text{Number } NO_x \text{ Molecules}}$ = 31.5

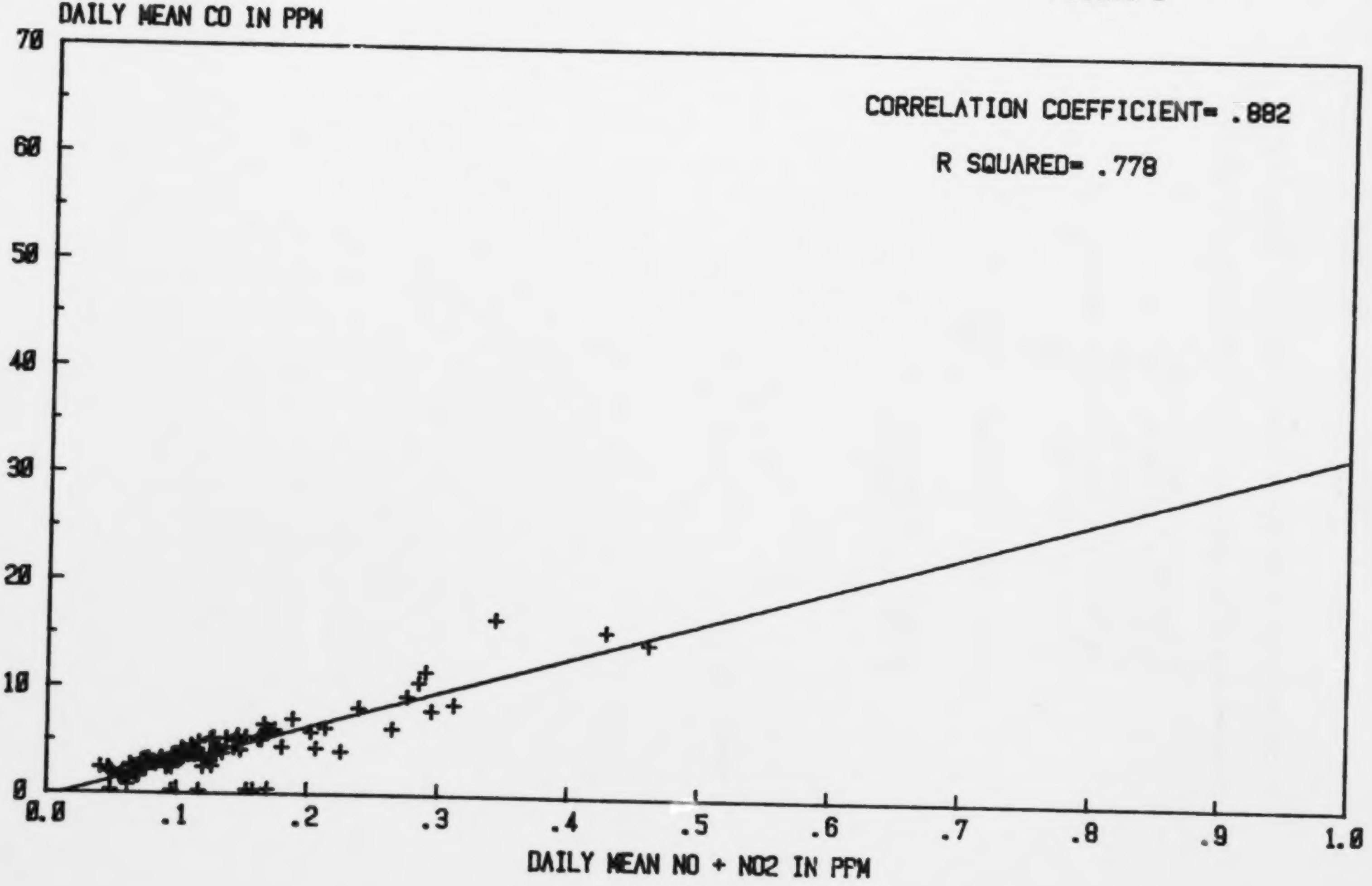
*Using Mobile 2

CO VS. [NO+NO2]-DAILY MEAN VALUE

DENVER CAMP STATION OCT-DEC/81

LINEAR FIT
CO=33.2X-.38

FIGURE 1

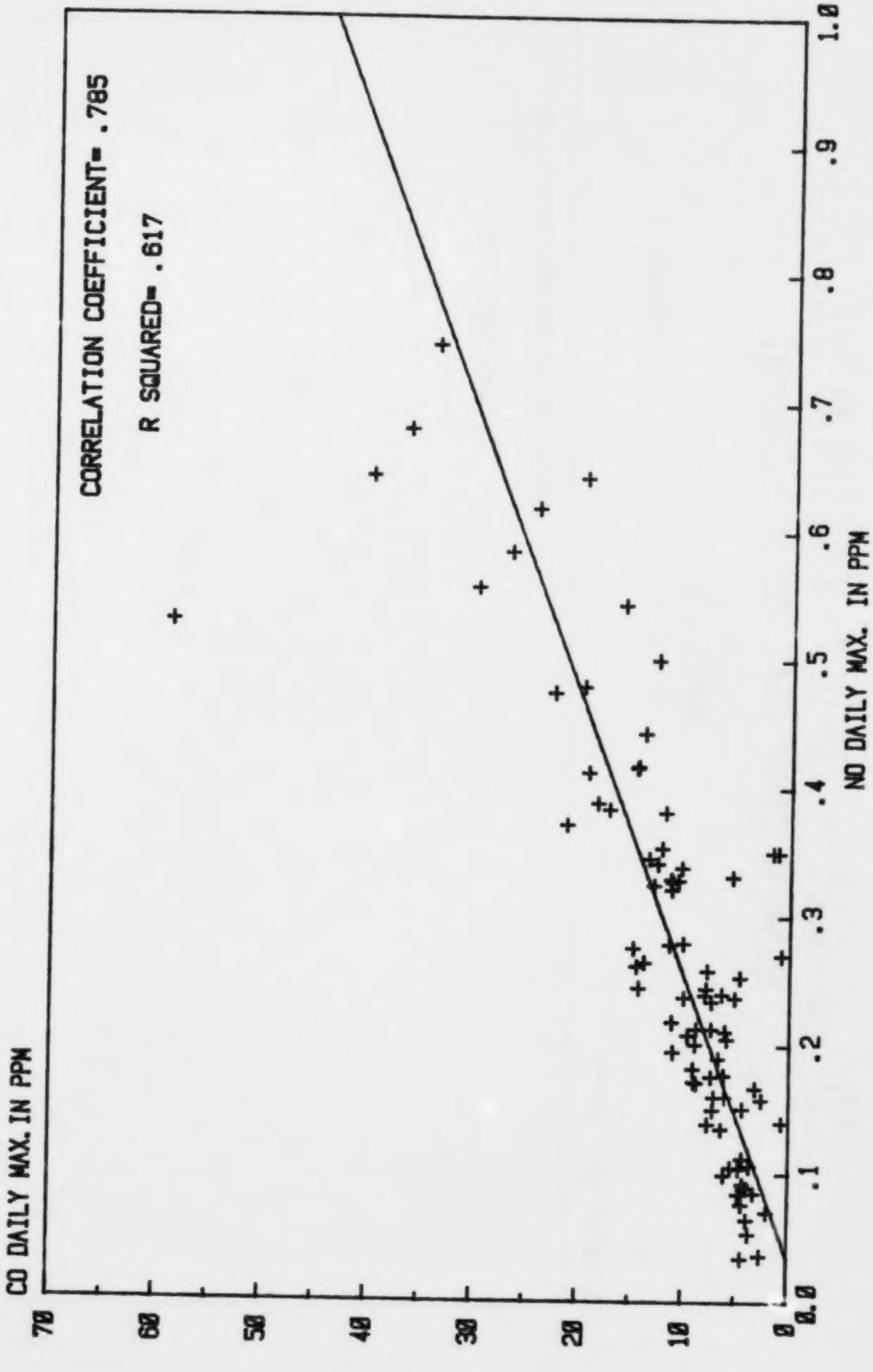


CO VS. NO - DAILY MAXIMUM VALUES

DENVER CAMP STATION OCT-DEC/81

LINEAR FIT
CO=45.7X-1.6

FIGURE 2

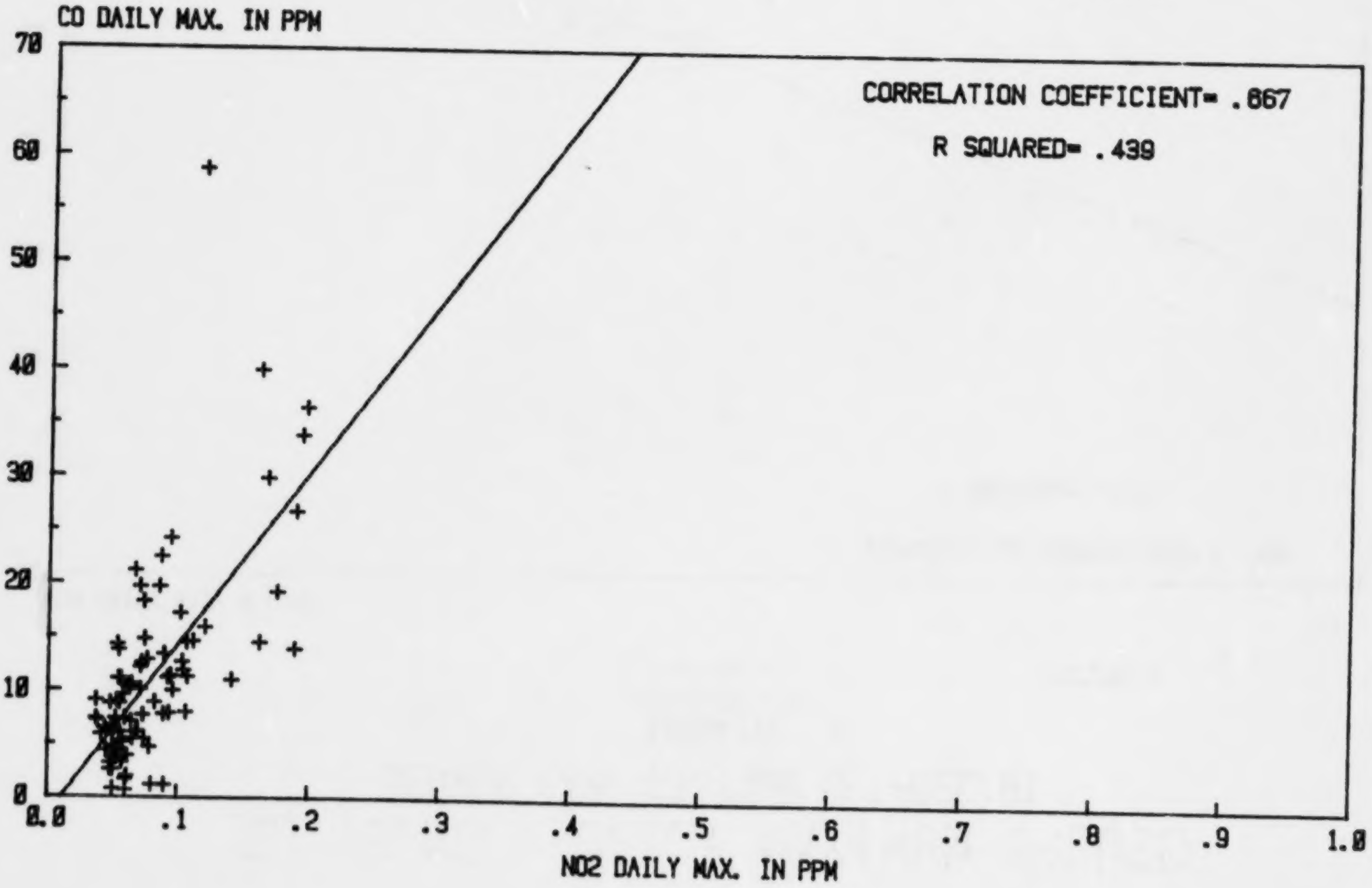


CO vs NO2 - DAILY MAXIMUM VALUES

DENVER CAMP STATION OCT-DEC/81

LINEAR FIT
CO=161X-1.75

FIGURE 3

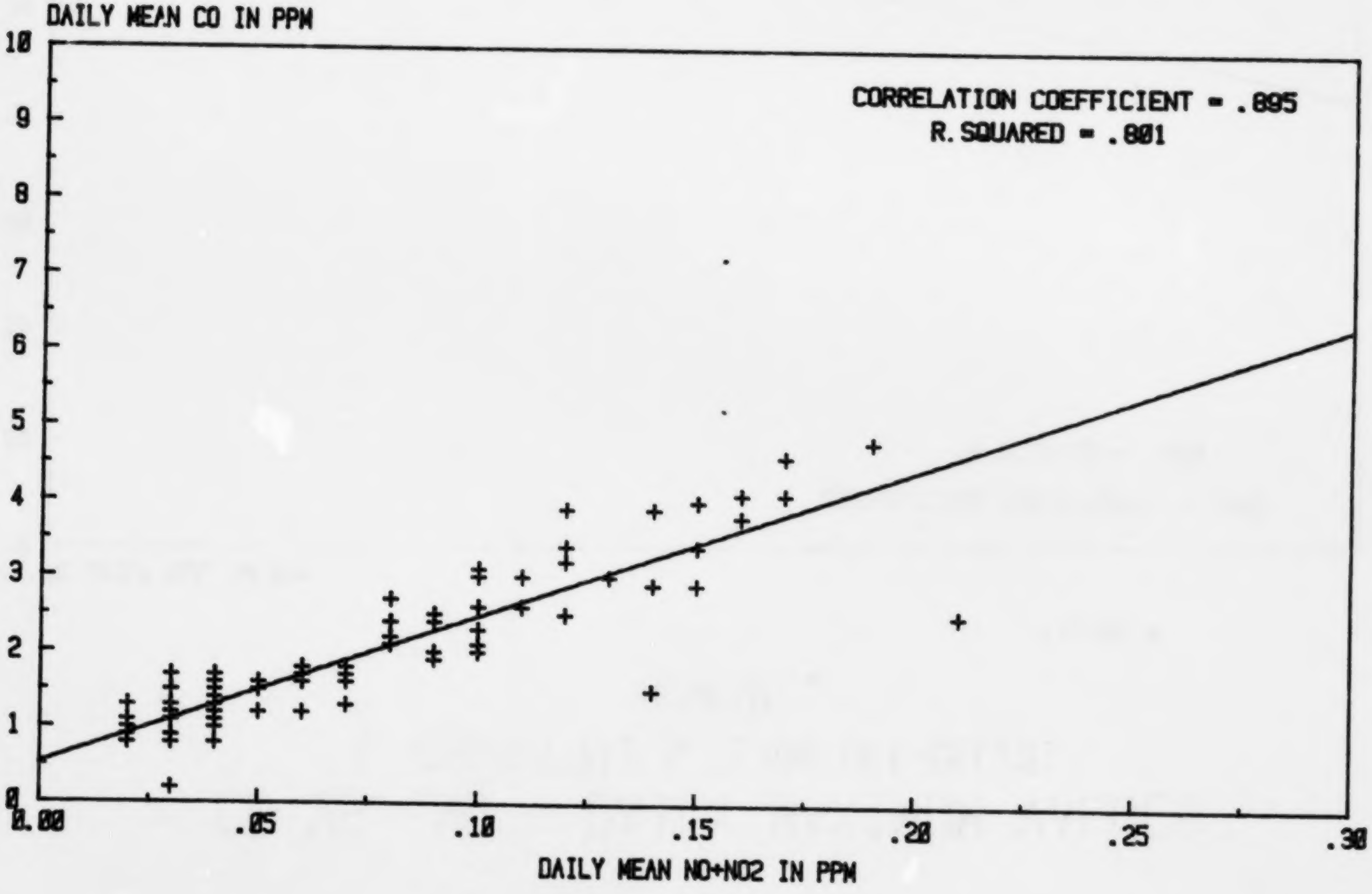


CO VS. [NO+NO2]-DAILY MEAN VALUE

C. SPRINGS 712 S. TEJON OCT-DEC/81

LINEAR FIT
CO=10.5X+.52

FIGURE 4



CO VS. NO - DAILY MAXIMUM VALUES

C. SPRINGS 712 S. TEJON OCT-DEC/81

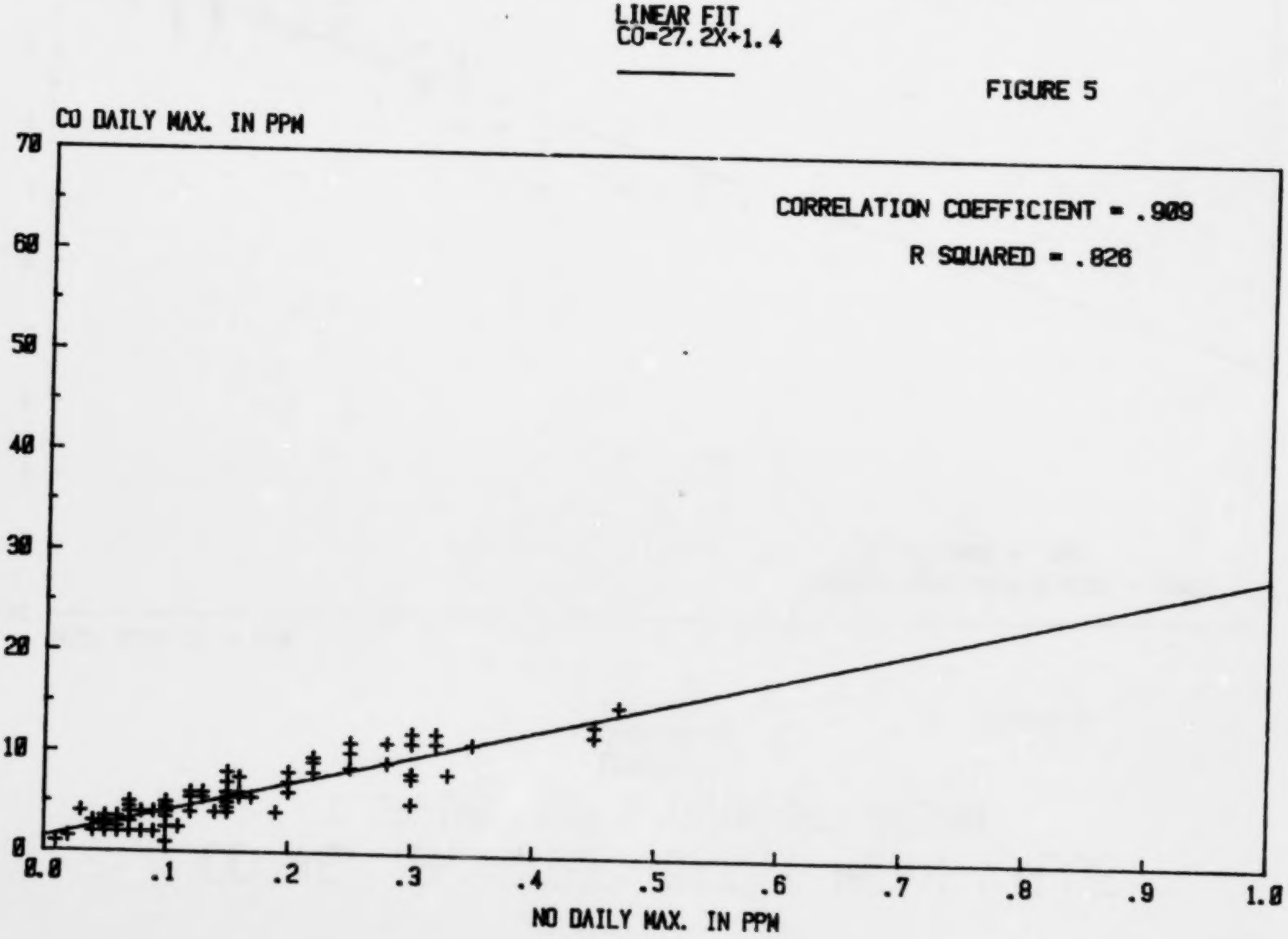


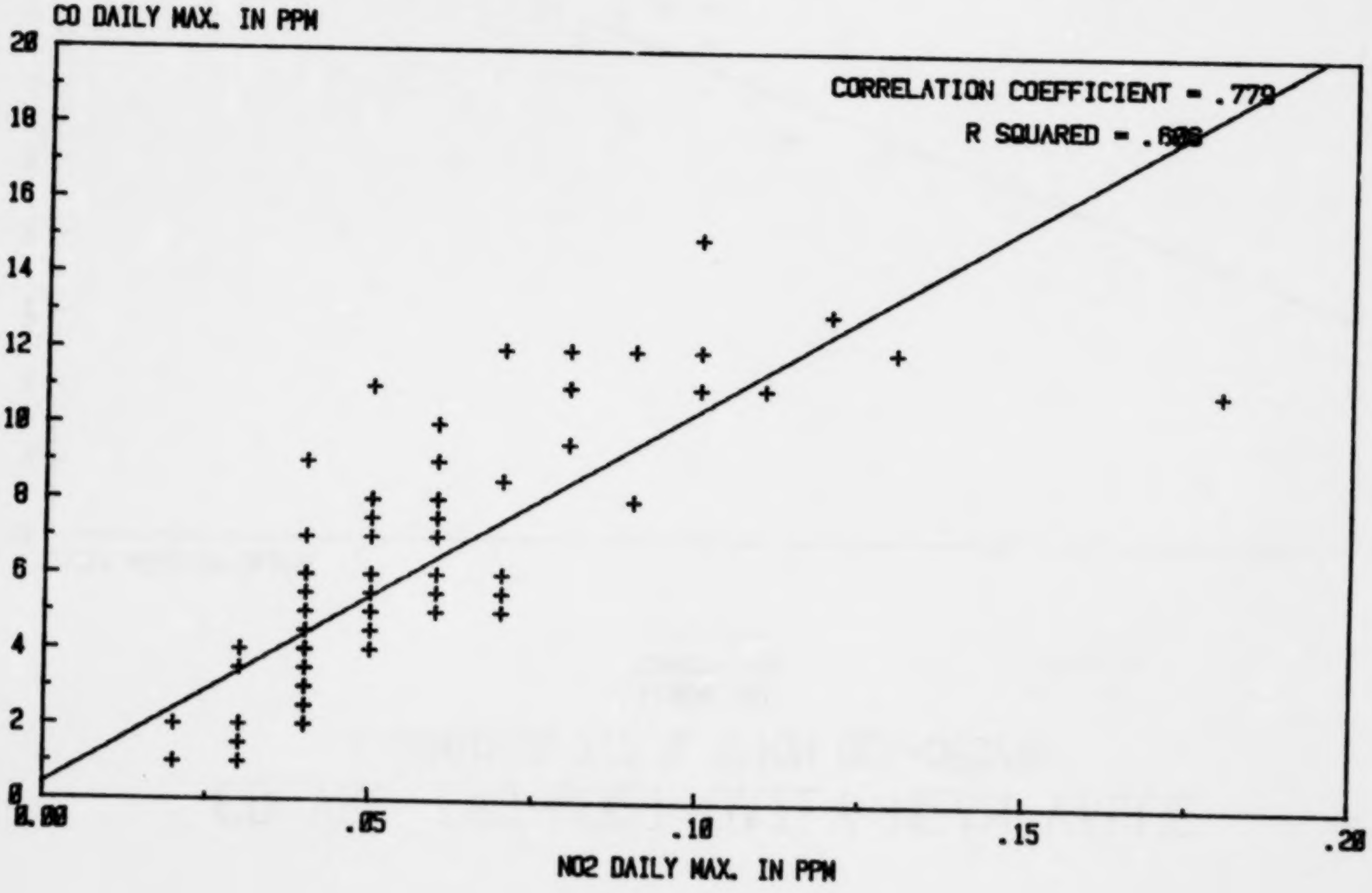
FIGURE 5

CO VS NO2 - DAILY MAXIMUM VALUES

C. SPRINGS 712 S. TEJON OCT-DEC/81

LINEAR FIT
CO=101X+.40

FIGURE 6

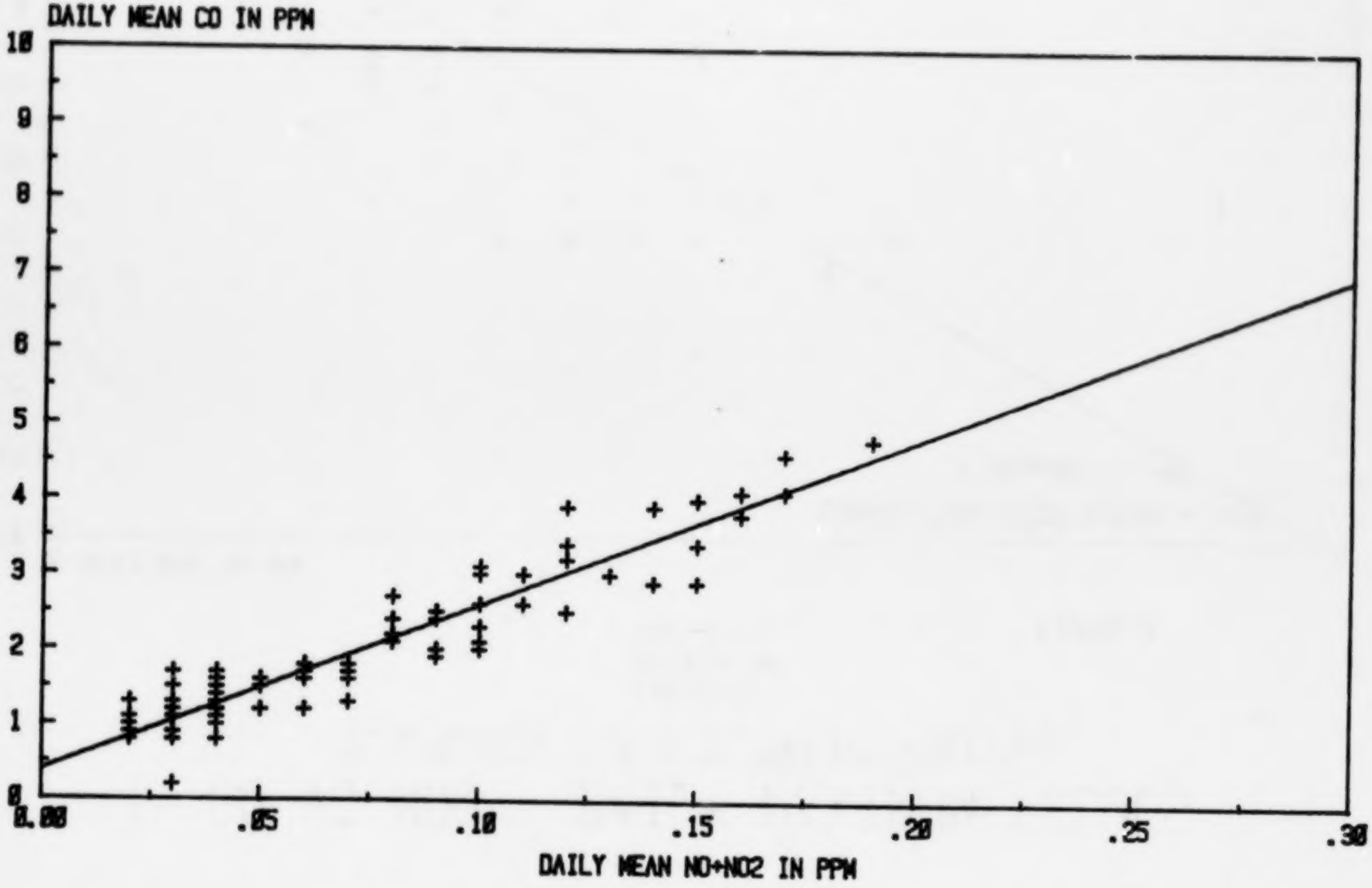


CO VS. [NO+NO2]-DAILY MEAN VALUE

C. SPRINGS 712 S. TEJON OCT-DEC/81

LINEAR FIT
CO=22X+.300

FIGURE 7



Gasoline Service Station Vapor Control Technology, Effectiveness, and Payback Economics
- A Status Report -

Robert D. Bradt, Ph.D.
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ABSTRACT

This is a report on the status of gasoline station vapor control in California as of early 1982. It is written by, and from the viewpoint of, one system developer.

SUMMARY

There are many advantages of gasoline station vapor control. It is an effective and efficient air pollution control technique. Its savings in gasoline conservation and recovery more than pay for the equipment and its maintenance. It substantially improves the fire safety of a gasoline station and the respiratory health of nearby personnel.

Gasoline Service Station Vapor Control Technology, Effectiveness, and Payback Economics
- A Status Report -

by
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This is to report on the status of gasoline station vapor control in California as of early 1982. This is written by, and from the viewpoint of, a vapor control system developer. The intent is to speak about California, not to speak for California.

After 10 years of experience with gasoline station vapor control in California, there are many important and optimistic observations to report. In summary, they are the following.

1) Gasoline station vapor control has proved to be primarily an energy conservation technique. The value of the gasoline conserved and recovered more than pays for the control equipment, its installation, and its maintenance. Of significance is the fact that the economic payback accrues directly to the person who makes the investment, rather than to some nebulus segment of society.
2) Gasoline station vapor control has proved to be a highly efficient air pollution control technique. Its cost effectiveness in terms of dollar cost per pound of hydrocarbon controlled is probably the best of any known high-volume technique. Indeed, with the payback from conservation, the cost is negative.
3) It has proved to be a valuable safety technique which relates to both fire and respiratory health in the immediate environment of the gasoline station, particularly with the advent of self service and its related public liability.

Major Program Ingredience

The experience in California appears to have established, tested, and validated the necessary ingredience for the program.

1) The technology-- which gets the job done efficiently and effectively while maintaining the speed, convenience, and cleanliness of gasoline dispensing. Convenience is particularly critical as more and more stations convert to customer self-service.
2) The legislation-- which is meaningful and tolerable for every faction involved: politician, industrialist, conservationist, state agency, gasoline marketer, station worker, and consumer.
3) The economics-- which demonstrates that the gasoline station's investment in the vapor control equipment is self-liquidating.
4) The implementation sequence-- which is effective for both the station owners and the state agencies
5) The litigation-- which has tested the legislation in the courts and found it valid and enforceable.
6) The competition-- which keeps the market healthy. About 6 competing vapor control systems have been certified for use and are in production. Two are of the "balance type". Four are of the "Vacuum assist type". These competing systems represent a broad spectrum of quality, cost, and applicability to gasoline stations of all sizes.

Payback Economics

The self-liquidating payback economics result primarily from the fact that when a vapor control system is installed, vapors are kept inside the system and fresh air is kept out. Figure 1 is an example of closed vapor control system piping. Some of the vapors which are recovered from the vehicle tanks are recondensed back into saleable gasoline. Some of the vapors are held as vapor in the storage tanks to blanket the stored gasoline and prevent evaporation, thus reducing to zero the previously uncontrolled loss called evaporation loss or vent loss. This is particularly true of a vapor control system which allows the storage tank vent risers to be closed.

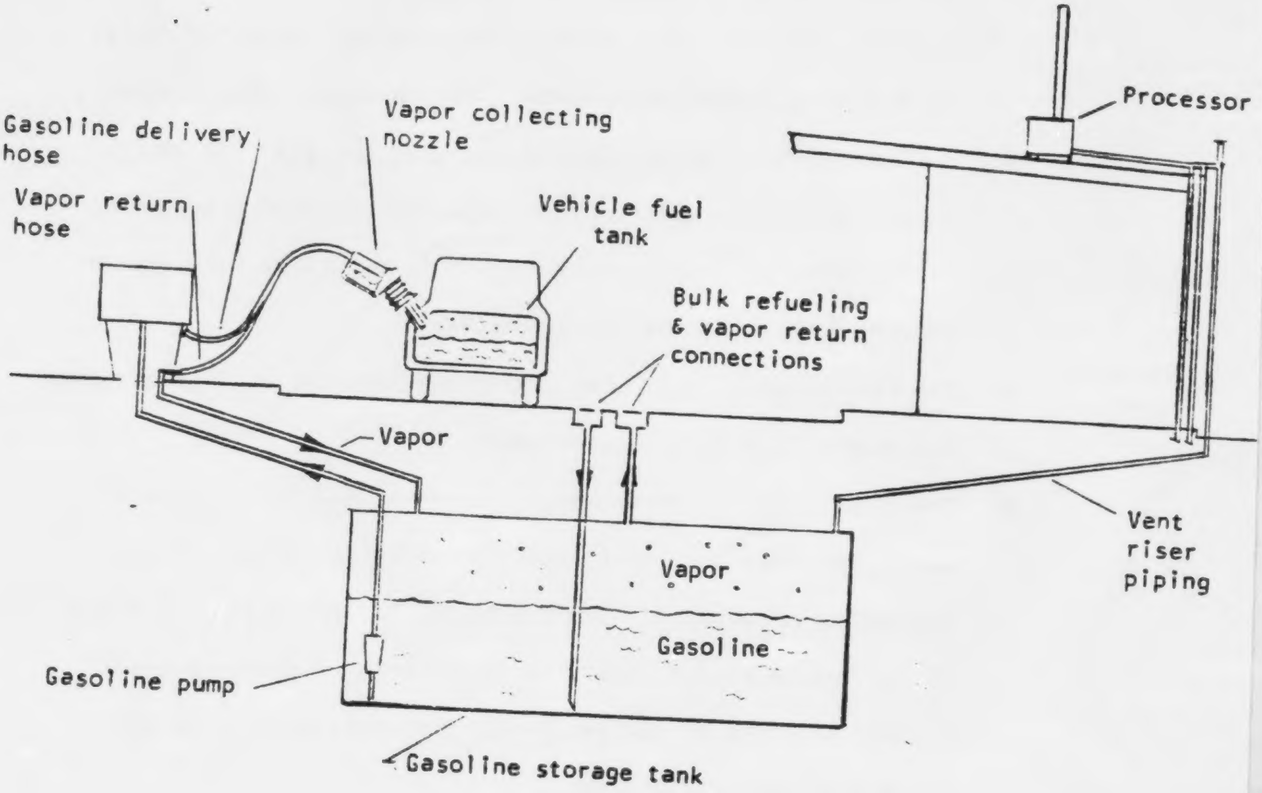
Gasoline delivery hose
Vapor return hose
Vapor collecting nozzle
Vehicle fuel tank
Processor
Bulk refueling & vapor return connections
Vapor
Vent riser piping
Vapor
Gasoline
Gasoline pump
Gasoline storage tank

Figure 1
Typical Installation
A Closed, Vacuum Assist, Processing System

Relative to hydrocarbon credits, how much gasoline is really conserved, and how much hydrocarbon vapor is really removed from the atmosphere; it is not the intent of this report to comment on how hydrocarbon credit calculations are made. It would be appropriate however, to note some facts. First, vapor collection efficiency in excess of 95% is well within the technology now in production and in use in California. Second, considering the question "Ninety-five percent of what?", the physical facts of gasoline stations dictate that the quantity of vapors available for control are as follows.

1) When a station's bulk gasoline storage tank is ready to be refilled, the total volume of the storage tank not containing gasoline, is filled with gasoline vapor i.e., air saturated with hydrocarbon. As the storage tank is filled by a bulk tank truck, this gasoline vapor is displaced at the rate of about a gallon for a gallon i.e., a gallon of gasoline vapor released for each gallon of gasoline supplied to the storage tank.
2) When a vehicle tank is ready to be refueled, the total volume of the tank not filled with gasoline, is filled with gasoline vapor. As the vehicle tank is filled, the vapor is displaced at the rate of a gallon for a gallon.
3) It follows that for every gallon of gasoline moved through a station and into a vehicle, there are 2 gallons of raw gasoline vapor displaced: one gallon displaced for each gallon of gasoline dropped into the station's storage tank; one gallon displaced for each gallon of gasoline dispensed into vehicles.

The quantity of gasoline conserved and recovered depends on several things such as the type of vapor control system used and the gasoline throughput of the station. The specific economics are set forth in detailed form for the Hirt Vapor Control System in a publication titled "Conserve the Midnight Oil", which is available from Hirt Combustion Engineers upon request.[1] In general, the evaluation goes as follows.

1) The total initial investment in a Hirt vacuum assist vapor control system is about $9,000 including processing device, nozzles, vapor return hoses, and installation labor. There is a 10% investment tax credit and a 10% energy tax credit available, which brings the initial investment to about $7300.
2) Maintenance and repair for the vapor control system runs about $900. per year.
3) The gasoline conserved and recovered runs between 0.1% and 0.2% of the station's throughput. For an average station with a throughput of 100,000 gallons per month, the savings will be between 100 and 200 gallons of gasoline per month. At $1.25 per gallon, that is between $125. and $250. per month or between $1500. and $3,000. per year.
4) Subtracting the yearly maintenance cost of $900. per year leaves a return of between $600. and $2100. per year.
5) A return of $2100. per year on a $7300. investment is 30% per year return on investment -- better than the current money market. Even the lower return of $600. per year is about 10% return on investment.

This economic evaluation considers only half the savings i.e., the half that accrues to the station owner. The other half is carried back to the terminal in the bulk truck as vapor. Savings from the recovery of that half accrues to the terminal operator, and the total of both halves accrue to the nation as conserved gasoline and as controlled emissions.

Additional Benefits

There are other benefits of gasoline station vapor control. They may be minor, unless they happen to you, in which case they can seem major. One relates to the fire and explosion safety of bulk gasoline delivery trucks driving on the public roads returning to their terminals. The safety of that truck depends largely upon whether the station at which it just dropped its load had a vapor control system or not. If the station did not, then as the gasoline ran out of the truck tanks, fresh air entered to replace it. It is probable that the mixture of fresh air and residual gasoline will form an explosive mixture. If however, the station had a vapor return system, the vapors from the station's storage tanks flow into the truck to replace the delivered gasoline. This vapor is too rich to ignite, thereby preventing the truck from being an explosion hazard.

Another minor benefit relates to water in the station's storage tanks. If the station has no vapor control system, fresh air is drawn into the storage tanks to replace the gasoline dispensed into vehicles. The fresh air contains natural moisture which tends to condense in the cool storage tanks. Each year or so, this water has to be pumped out of the storage tanks to prevent it from being dispensed into vehicles.

Over the past few years, there have been many rumors and public media reports about the successes and failures of the gasoline station vapor control program in California. Some true, some untrue, some discussing technical problems long since solved, and all much exaggerated. States and districts considering gasoline station vapor control on solid economic and technical grounds would be well advised to assess the factual status of the program in California, and not the rumors, or out-dated reports in the press.

Conclusion

Gasoline station vapor control is at work in California. It is one of the very few conservation/pollution control tactics for which the technology, currently in production, prevents the contaminate from entering the atmosphere, converts the contaminate directly back into saleable product with no reprocessing, reduces fire hazard, conserves gasoline, improves the nation's balance of trade -- and makes the gas station operator a respectable return on his investment.

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PROJECTED CONTROLS

THE VEHICLE MANUFACTURERS LOOK INTO THE FUTURE

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Peter Drucker, the noted management consultant, said we really can't predict the future -- all we can do is extrapolate from the present.

It is impossible to extrapolate present automotive emission controls into the future without simultaneously extrapolating trends in fuel economy, vehicle configuration, power plants, and fuels since they are all interdependent. From the manufacturer viewpoint, fuel economy and vehicle configuration might be considered the independent variables in the group since customers decide the configuration and fuel economy they will accept and Federal and state regulators decide the safety, fuel economy and emission standards that must be met. It is up to the automotive and petroleum engineers to develop the engines, fuels and control equipment -- the dependent variables in the equation -- to satisfy the demands of the vehicle buyer and the regulator.

With Dr. Drucker's advice in mind, let's consider the future for each of the variables.

First, there's fuel economy. I don't think any of us believe that the current oil surplus is any more than a momentary dip in a long range pattern of rising costs and diminishing supply. Thus, it seems certain that improved fuel economy has become a permanent, although flexible, feature of customer demands.

Second, and equally as strong as the demand for fuel economy, is the demand for certain minimum levels of comfort and convenience.

The manufacturer is continuously faced with the necessity to satisfy those frequently conflicting demands.

A recent University of Michigan survey of domestic motor vehicle manufacturers' opinions reveals that by 1990:

1. The spark-ignited reciprocating engine will continue to be the dominant automotive power plant.

2. The price of gasoline will rise to the $3.00 - $4.00/gallon level and diesel fuel will be $2.50 - $3.50/gallon.

3. The average fuel economy, based on the EPA urban cycle, will be in the 35-45 mpg range and by the year 2000 in the 45-60 mpg range.

4. Fifty percent of the continuing improvement in fuel economy will come from downsizing and weight reduction, 25 percent from improved engines and drivetrains, and the remainder from improved aerodynamics, reduced tire rolling resistance and increased use of electronic controls.

5. The average curb weight of the 1990 car is estimated at 2250 pounds as compared to 3300 pounds for the 1980 model..

6. The installation of accessory equipment such as power brakes and power steering will decrease but the percentage of vehicles equipped with air conditioning will stay approximately the same.

7. Seventy-five percent of the light-duty vehicles will be front-wheel drives.

The same survey also expressed the motor vehicle manufacturers' opinions on the status of the automotive power plant and drivetrain in 1990. The manufacturers surveyed believe:

1. More than two-thirds of the passenger car engines will be four cylinder and most of the remainder will be six's. The eight cylinder engine will all but disappear and there will be some evidence of three or even two cylinder engines in the marketplace.

2. One-third of the passenger cars built in 1990 will have four or five speed manual transmissions. The remainder will be three, four, or five speed automatics, but virtually no penetration is seen for the continuously variable transmission primarily because of cost. Virtually all automatics will have the lock-up feature.

3. The most important technological advances will be seen in the fields of electronic controls, air/fuel improvements, combustion chamber design, and supercharging/turbocharging.
4. Diesel engines will be installed in about 25 percent of the passenger cars and light-duty trucks by 1995. At that same time, electric vehicles will constitute three to five percent of production. Little or no penetration of the hybrid vehicle is expected.
5. Little or no change is expected in the cost to the customer of proper maintenance except to compensate for inflation.

Discussions with engineers from MVMA member companies gives a little better insight into the apparent future of various power plants considered for automotive applications.

Gasoline Engine

There are a number of improvements in various stages of development and testing applicable to the conventional gasoline engine.

Today, gasoline engines for light-duty vehicles require EGR and the three-way catalyst to enable tailpipe NO_x emissions to meet the applicable standard. Unfortunately, as the EGR rate is increased, fuel economy and driveability frequently suffer.

It has been determined that higher EGR rates and lean A/F mixtures can be tolerated without adversely effecting fuel economy and driveability by increasing the burn rate of the fuel. Using this knowledge, the fast burn technology is being developed. This technology uses high energy ignition and the combustion chamber is redesigned so that its geometry enhances flame accessibility. The incoming charge is very turbulent, and spark plug is optimally located.

The benefits derived from proper integration of these elements gives improved combustion stability, higher EGR tolerance, lower NO_x, high thermal efficiency which results in better fuel economy, lower octane requirements, higher compression ratio and reduced cycle-to-cycle torque variations for improved driveability. A disadvantage of this design is that its exhaust temperatures are lower and HC emissions are increased. Consequently, it is important to conserve exhaust heat by shortening the exhaust parts, using insulation, and moving the catalyst as close to the engine as possible.

Another area under study is the achievement of greater efficiency through lower rpm and reduced bore-to-stroke ratios. This design has the advantage of lower friction losses and higher compression ratio but it results in a heavier and taller engine.

A feature that should receive wider acceptance in the future is the knock-detector system. In this system, a detonation sensor detects the initiation of knock and transmits a signal to the distributor to retard the spark timing.

A number of programs are underway to reduce friction in the engine. They include rolling elements in the valve gear train, improved bearing design, reduced piston ring tension and low friction oils. Individually, the contribution of these items to improved performance and fuel economy and reduced emissions is small but their collective effect is significant.

A major step forward in improved engines of the future will be the adoption of fuel injection systems. The fuel injection system receiving the most consideration for gasoline engine applications is central or throttle body fuel injection. In this system, the fuel is presented to the induction air at the throttle. Fuel flow through the injector is precisely controlled by a microprocessor.

A second method of fuel injection, now receiving increasing attention, is multi-port injection. This method places an injector at each inlet port. Obviously finer control can be realized with this system but only at a much higher cost.

The advantages of fuel injection over carburetion are:

1. Reduced air/fuel ratio variability for improved emissions control and performance.

2. Improved matching to specific operating requirements, including variations in altitude and temperature.

3. Reduced evaporative fuel losses because there is no fuel bowl.

4. Elimination of engine run-on since fuel flow stops immediately when engine is shut off.

The possibility of extracting EGR gases at the exhaust port rather than from the exhaust manifold is being considered. The last portion of exhaust gas leaving the combustion chamber is normally the highest in HC concentration. Because this portion remains at the exhaust port until the following exhaust stroke, extracting these with high HC concentrations should reduce the exhaust HC delivered to the catalyst and ultimately to the tailpipe. A summary of several tests conducted on a 1978 model car showed a 13 percent reduction in tailpipe HC, a 17 percent reduction in CO but an eight percent increase in NO_x. Study of this approach is continuing.

The use of electronics for emission control and other functions will continue to expand. The basic components of the electronic emission control system are a three-way catalyst, an oxygen sensor, a microprocessor, and an electronically controlled carburetor.

The complexity of these systems can range from the modulation of air/fuel ratio and secondary air to interactive systems which simultaneously monitor and control EGR flow, spark timing, idle speed, cruise control, secondary air, spark knock, evaporative control devices and air/fuel ratio.

The three-way catalyst must operate within a very narrow range of air/fuel ratios for maximum efficiency. This range embraces the area from stoichiometry to slightly rich (less than one A/F ratio).

Electronics also have the potential to perform self-diagnosis, either continuously during vehicle operation or upon specific command initiated by a service technician. Such an electronic system may verify sensor input valves and strategy execution, light warning lights, and generate diagnostic information to describe the nature of the observed defect. Both steady-state and intermittent failures would be accommodated.

Diesel Engine

At 1981 emission levels, the diesel engine offers about a 25 percent fuel economy improvement over equivalent performance gasoline engines.

Diesel engine fuel economy can be further enhanced by supercharging or turbocharging. These two techniques are more attractive for the diesel because the knock and warm-up problems associated with gasoline engines are missing.

Most of the diesels used in today's light-duty engines use indirect injection, while many of the heavy-duty diesels are direct injecting. The direct injection engine can give 15 percent better fuel economy than the indirect injection engine but it has problems such as higher emissions and lower smoke-limited power.

The diesel engine has no problem meeting the 1981 model year HC and CO standards but there is a major difficulty in meeting the particulate and NO_x emission standards. For the most part, the 1982 standards of 0.6 grams per mile particulate and 1.0 grams per mile NO_x was met satisfactorily only after the NO_x level is waived to 1.5 grams per mile. I have seen no evidence that the 1985 standards of 0.2 grams per mile particulate and 1.0 grams per mile NO_x have been met for any significant mileage even on an experimental basis.

Particulate emissions are caused by insufficient mixing of the injected fuel and oxygen around the individual fuel droplets prior to combustion. Although particulates can be reduced by combustion chamber and calibration optimization, they cannot be completely eliminated. Particulates are primarily carbon or carbon compounds, 0.1 micron or less in size, having low bulk density.

It is necessary to discuss NO_x and particulate emissions together because particulate emissions increase as NO_x is controlled through EGR. In efforts to meet the 0.2 grams per mile standard by improving the combustion system, literally thousands of combinations of prechamber designs, main chamber designs, fuel spray patterns, and techniques such as air blast injection, fuel fumigation, pilot fuel injection and fuel heating have been evaluated. To approach the 0.2 grams per mile particulate emission standard, a particulate trap is necessary in all but the lightest vehicles.

Candidate trapping materials include alumina coated wire wool, porous ceramic substitute, and disposable paper. The first two represent the most promising alternatives; however, even these materials must be improved to have adequate temperature capability to withstand the required particulate oxidation process. The paper has high trapping efficiency but required too frequent replacement, even at the 0.6 grams per mile level. Even at that standard, a particulate trap must capture about 14 gallons by volume for every 10,000 miles travelled.

If trapped particulates are not removed every 300-600 miles, the back pressure build-up caused by the trapped particles will severely affect fuel economy and performance. To control this rapid build-up without inconveniencing the customer, an automatic trap regeneration system must be utilized.

Regeneration requires an exhaust temperature in excess of 900°F. This temperature is above the normal diesel road load exhaust temperature, so some external device must be used to raise temperatures above the 900°F level. Throttling the engine will raise the exhaust temperature to that level. However, a speed of at least 35 mph must be maintained for four or five miles to assure complete regeneration. Applying a catalyst to the trap material can lower the ignition temperature substantially, but a durable catalyst has not been found. There is also some evidence, being evaluated in greater depth, that fuel additives containing common metals such as lead, manganese, or copper, can lower the temperature at which the trapped particles will ignite.

Additional study is also being given several systems which entail burning supplementary fuel and installing bypasses in the exhaust system. These systems, at their present state of development, are expensive, fuel consumptive, unreliable and not durable.

A recent report from Southwest Research Institute states that a 1981 Volkswagen Rabbit with diesel engine was driven on a 50,000 mile durability run using a catalytic filter to control particulate emissions. The filter system, developed by Johnson-Mathey, was subjected to periodic regeneration procedures. At the end of the 50,000 mile run, particulate emissions were 0.167 grams per mile -- well below the 0.2 grams per mile standard.

While one test does not constitute a major breakthrough, it is very encouraging and we can only hope that subsequent testing will continue to support these findings.

Alternate Engines

There are several alternate engines that have received consideration for many years as possible replacements for the internal combustion engine. Although no power plant can be considered the permanent answer -- remember the steam locomotive and the clipper ships -- none of the alternates receiving consideration today are considered serious short-term threats. The reason is that none possess the combination of different requirements -- high fuel economy, low emissions, operational simplicity, easy starting, good performance, low noise, minimal maintenance, and low cost -- to the degree that the internal combustion engine possesses.

Let's briefly look at some of these engines.

Gas Turbine

The major attraction of the gas turbine is its ability to operate on a wide variety of less refined, and hopefully less expensive, fuels and its low emission levels.

The application pre-mixing and pre-vaporizing techniques upstream from the flame zone permits the attainments of emission levels of 0.26 grams per mile HC, 0.98 grams per mile CO, 0.30 grams per mile NO_x and 0.002-0.007 grams per mile particulates.

However, the gas turbine has its disadvantages: fuel economy on conventional liquid fuels is significantly poorer than for the spark-ignition engine. Using current technology materials, the turbine will cost about 40 percent more than a conventional gasoline engine. New higher-temperature experimental turbine-wheel alloys must be demonstrated -- there are numerous efforts in progress to develop ceramic materials for this application -- and maintenance techniques and procedures must be simplified. It does not appear that the disadvantages can be overcome in the next ten years but given the uncertainty of future fuels, the turbine will continue to receive attention.

Stratified Charge Engines

Stratified charge engines promise outstanding fuel economy and good NO_x control but there are major problems with hydrocarbons. Texaco and United Parcel Service (UPS) have recently completed a test program in which Texaco-designed stratified charge engines were installed in UPS trucks and driven in normal delivery operations. I have not seen a final report of this venture but apparently both companies are very satisfied with the results.

Advanced designs of the stratified charge engine, using turbochargers to extend its fuel economy and its low NO_x capability, may make this type engine very desirable in heavy-duty truck applications.

Electrics

The electric car is still waiting for the big battery breakthrough. It is probably further from volume production than the other alternatives, although General Motors has promised a zinc-nickel oxide battery-driven commuter car by the late 1980's. In addition to the battery breakthrough, other unresolved technical problems include further improvement in motors and controls, developing a reliable indicator of how much energy is left, and questions of servicing, safety, and economics.

Electric car researchers visualize a car that will be made of exclusively light weight materials because each additional pound in an electric vehicle has as much effect on driving range and performance as three pounds in a conventionally powered vehicle. The electric vehicle would carry two passengers, have storage space for several bags of groceries, be aerodynamically clean, and have low rolling resistance tires. There would be no air conditioning.

The target range would be 75-80 miles on the Federal test procedure or 100 miles at a constant speed of 45 mph between charges. A top speed of 45 mph with acceleration from 0 to 30 in eight seconds is anticipated.

The battery must be fully rechargeable in eight hours with a life of 300 full discharge cycles or 30,000 miles. The most likely candidate to achieve these levels is the zinc-nickel oxide battery.

I should point out that electric vehicles utilizing oil-generated electrical power will produce no real reduction in our nation's oil consumption. When oil is used for electric power generators to be used in charging and powering electric vehicles -- the overall energy efficiency is 16 percent. When oil is refined and burned in internal combustion engines, the overall efficiency is 16 percent.

Other Alternative Engines

Several alternate engines have more-or-less fallen by the wayside. These include the free-piston engine, the Rankine cycle or steam engine, and the Sterling engine.

Alternate Fuels

The last variable in our equation is alternate fuels. While gasoline and diesel fuels meet the current needs of the world, future energy needs are not likely to be filled by any one fuel because the availability and economics of the many alternate fuels vary in different parts of the world. Four fuels appear to have a fairly wide spread base, making it feasible to consider development of engines to utilize these fuels. The fuels are propane or LPG, natural gas and two alcohol fuels -- methanol and ethanol.

Propane or LPG

At the present time there are an estimated 750,000 propane fueled vehicles on the road. Many of these are designed for dual-fuel operation. Because LPG has an energy content three-quarters that of gasoline, such systems are always compromises that render it impossible to take full advantage of the combustion characteristics of either fuel. LPG can be stored at relatively low pressures, approximately 100 psi.

An engine built for exclusive operation on LPG could be designed to take advantage of its higher octane qualities (103-105 RON). Storage space for fuel outside the vehicle body would present a minor problem but a 25 gallon tank should give the vehicle a range of 400 miles. The compression ratio would be increased to 10.5:1 and the induction system would be modified for increased charge intake.

Extensive development work on high altitude, hot weather and cold weather performance and crash testing is underway. Typical emissions data from an LPG fueled vehicle show HC - 0.75 grams per mile, CO - 1.06 grams per mile, and NO_x - 1.58 grams per mile. Fuel economy ranges from 15.2 mpg urban to 22.2 mpg highway.

The major obstacle to wide use of LPG vehicles seems to be the lack of a sufficient supply and distribution facilities of LPG, although a vehicle in the U.S. with a 400 mile range might warrant consideration.

Natural Gas

As with LPG, there are about 20,000 natural gas dual-fueled vehicles on the road, with the same inability as noted for LPG to get full response from either fuel.

The typical dedicated natural gas vehicle stores its fuel in high pressure tanks (2400 psi) located, at least partially, in the trunk. The trunk must be sealed off from the passenger compartment and several vents are installed. The engine has a 14:1 compression ratio because natural gas has a 130 RON.

There is some experimental work underway with on-board liquified natural gas systems but the logistic problems associated with storing sufficient quantities of this fuel probably preclude its acceptance on the public highway.

Natural gas fuel will yield low emissions with no deposit or particulate problems. The fuel has excellent warm-up characteristics and does not dilute the motor oil. Safety questions are the major disadvantages. These problems include adequate venting, on-board storage at 2400 psi, and accident security.

There is no distribution system in place for refueling natural gas vehicles. However, such systems exist in New Zealand where natural gas is abundant and in Italy where 250,000 vehicles have been converted to natural gas operation.

Alcohol Fuels - Ethanol and Methanol

Both of these fuels have characteristics which make them very desirable for internal combustion engines. They offer improved thermal efficiency and research octane numbers in excess of 100.

In the U.S., Germany and New Zealand, methanol seems to be of greater interest. The rest of the world favors ethanol. Methanol enjoys greater interest here because it can be produced from a far broader list of raw materials.

Ethanol is derived primarily from the fermentation of grain -- thus there is the constant threat of pestilence, drought, flood and the food needs of the world influencing the availability of the raw material. It has been estimated that the entire state of Iowa would have to be planted in corn to furnish 10 percent of the country's gasoline requirements. However, these are renewable sources.

Methanol, on the other hand, can be produced from coal, shale, and almost any kind of biomass. Obviously, the experts look to coal and the vast oil shale and coal tar deposits in the West to furnish the bulk of the replacement for petroleum-derived gasoline and diesel oil. However, wood chips, garbage and non-edible vegetable products grown specifically for fuel production may fill some local needs.

Vehicles fueled with neat ethanol (actually 95 percent ethanol, 5 percent water) are presently in production in Brazil. Recently, this program has suffered a set back because of the withdrawal of some governmental support for ethanol and the world-wide petroleum glut, but this set back is viewed as only temporary.

Even though the energy content of ethanol is only two-thirds that of gasoline on a volume basis, the increased efficiency of the ethanol engine gives it a fuel economy of more than 80 percent of an equal volume of gasoline. In other words, in terms of energy content, ethanol is more efficient. Four-day road tests on a 1.6 liter Ford vehicle built in Brazil shows gasoline yielding 27.3 miles per gallon and 23.5 miles per 100,000 BTU. The same car fueled with neat ethanol gave 24.3 miles per gallon and 31.9 miles per 100,000 BTU.

Relative to gasoline, alcohol fuels have a high heat of vaporization, low stoichiometric air-fuel ratios and low vapor pressure -- all characteristics which contribute to poor driveability. Cold starting poses a particular problem. This can be overcome with manifold heaters and special starting fuels, but only by decreasing the overall efficiency.

Methanol, on the other hand, has about one-half the energy content of gasoline on a volume basis and requires more changes to engine components. A methanol engine, being tested by Ford in Brazil has a compression ratio of 13:1, an exhaust heated intake manifold and electric heaters to be used for cold start below

$50^{o}F$. Material changes to avoid corrosion include a chromatal zinc carburetor body, stainless steel needle valve, nylon fuel lines and a tin lined fuel tank.

Certain changes are essential to the conventional gasoline engine if alcohol fuels are to be used. The capacity of the fuel storage and delivery system must be enlarged. The compression ratio should be increased to take advantage of the higher octane and special pains must be taken to prevent pre-ignition. Compatibility of the alcohol fuels with the fuel system must be considered.

Methanol is more corrosive than ethanol and thus merits even greater attention. It will attack the lead lining in the fuel tank and the carburetor float bowl. Various elastomeric components are subject to deterioration or swelling. Any moving parts depending on fuel for lubrication will be subject to greater wear. The long-term effect on lube oil and engine durability requires special study. To insure acceptable driveability, the carburetor in the methanol-powered vehicle may have to be replaced with fuel injection.

Exhaust emissions are another concern. CO and NO_x generally present no problem, particularly if EGR and the oxidizing catalyst are used. However, emissions of unburned fuel and HC products of incomplete combustion may be as much or several times greater than those from a gasoline engine of equal compression ratio. The problem that this presents to ambient air may not be significant and needs further study because the reactivity of the alcohol-based emissions is lower than for gasoline engines. Aldehyde emissions are significantly higher and they are known contributors to the photochemical smog reaction. The impact of aldehydes on the public health is the subject of extensive current research. Major obstacles to production of a methanol-fueled vehicle would be with fuel production, distribution and general availability in the marketplace. The primary problems associated with the engine, such as cold start and material compatibility and durability, can readily be solved before the methanol fuel is widely available.

Synfuels

Some mention should be made of the synfuel situation. At the present time, a very few synfuel pilot plants are being constructed near the Western U.S. shale and coal tar deposits. The product of this synfuel distillation can then be reformed into methanol, gasoline or diesel fuel. There are apparently enormous environmental problems that must be resolved before synfuel production is a viable process.

At the present time, there is not enough of any particular synfuel available to permit large scale evaluation of its performance or emissions.

Hydrogen

In many scientist's minds, the ultimate fuel is hydrogen. Hydrogen ideally can be produced by huge nuclear generating stations located in salt water areas such as the Gulf of Mexico and California. Nuclear power can dissociate salt water into atomic hydrogen and nitrogen. The nitrogen is released to the atmosphere while brine and other compounds are returned to the ocean. The hydrogen is liquified, transmitted to the mainland and stored in cryogenic tanks.

Wholesale conversion to hydrogen is obviously many years away and the willingness on the part of the individual states to transport, store and distribute it must be assured before the hydrogen program moves forward.

A second hydrogen system revolves around the dissociation or reaction of methanol to produce atomic hydrogen and CO_2. This process, known as reformed methanol, is very much in the research phase.

The desirable feature of hydrogen as a fuel is that of its exhaust products -- CO_2, water and NO_x -- only the NO_x must be controlled and it is possible that proper combustion chamber design and combustion control can hold this undesirable emission to a minimum.

Emissions Control Technology

Today, we are attempting to meet the ultimate levels of motor vehicle emissions control. For light-duty gasoline vehicles, those levels are technologically achievable through the use of three-way catalysts, electronic sensing and feedback control although there is ample scientific evidence to believe that less stringent standards will permit attainment of ambient standards and provide adequate protection for the public health.

The standards presently required for 1984 heavy-duty gasoline engines will require the catalytic converter. There has been no evidence that a catalytic converter has been developed that will provide durable operation under the temperatures, exhaust gas mass flow, and loads associated with heavy-duty engines.

Attainment of the required NO_x standards may be questionable even if electronic sensing and feedback control are added. Based on the latest ambient air quality levels and trends, it does not appear that standards as stringent as those proposed are necessary to meet the ambient air quality standards. More reasonable standards may be attainable using established technology.

The diesel engine is faced with the additional problem of meeting a particulate standard as well as the HC, CO and NO_x standards. At the present time the heavy-duty particulate standard has not been established so it is impossible to determine the technology required to meet it. However, the inverse relationship noted for particulates and NO_x for the light-duty diesel is equally applicable to the heavy-duty diesel. The problems associated with particulate control and particulate traps were discussed earlier.

The alternate engines and fuels receiving serious consideration at the present all seem to yield basically lower emissions than the gasoline and diesel engines although very little is known about the operating emissions of the various synfuel products. Control of HC, CO and NO_x, at levels necessary to meet the ambient air quality standards, appears to be within the scope of existing technology. Particulate control may depend on the development of a practical trap. It is always possible that combustion of some of the alternate fuels may result in the emission of pollutants not controlled at the present time.

Closing

I had occasion a few weeks ago to review some comments made by the Los Angeles Air Pollution Control District and the California Motor Vehicle Pollution Control Board in the 1950's. I was amazed by the number of statements by scientists, regulators and elected officials that predicted a complete solution to the air pollution problem in two or three years. Since then I think we have become less naive about the difficulties of solving the pollution problem.

The French philosopher, Paul Valery, once said, "The trouble with these times is that the future isn't what it used to be." Twenty-five years of industry and regulatory experience in trying to control automotive emissions certainly proves that Valery was right.

THE SIGNIFICANCE OF ENGINE WARM-UP TIME ON CARBON MONOXIDE EMISSIONS FROM MOTOR VEHICLES

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Objective

The objective of this study is to illustrate the necessity and significance of modifying the methods used to model carbon monoxide (CO) emissions from motor vehicles. Low ambient temperatures in Alaskan cities dictate this revision, however, this methodology also applies to more temperate regions. Two test cases will be used for illustrative purposes.

Introduction

It is well known that cold temperatures increase emissions from motor vehicles. (1) Specifically, it is the early portion of the driving cycle, when the engine is cold, that is most influenced. Given the tendency of people to warm up their engines prior to driving, it is possible that a significant portion of the trip emissions occurs during that time. For the purposes of analysis, emissions can be differentiated between two phases: the initial start-up and warm-up of the vehicle and its normal hot operation. The former is characterized by a rich fuel mixture in the combustion system and the vehicle in stationary. This initial operation will be referred to as the cold start.

During hot operation, regardless of ambient temperature, emissions are primarily affected by the state-of-tune of the vehicle and whether or not the emission control equipment is effective. It is also the phase when the vehicle is in motion, hence, the distance the vehicle travels is an important factor.

Cold Start

A schematic of cold start emissions is shown in Figure 1. Because the choke is engaged, there is an immediate rise in emission concentrations to a plateau. A similar, but less pronounced effect occurs for non-choked vehicles. This is maintained for a few minutes and then gradually reduced to the low level (stabilized emissions) associated with the warm idle. It is the effect of the cold start that requires temperature corrections to be made when calculating emission factors.

The current Environmental Protection Agency (EPA) methodology used in generating emission factors is the Federal Test Procedure (FTP). Emissions are separated into three distinct operational categories: cold transient, stabilized and hot transient, referred to as Bag 1, Bag 2 and Bag 3, respectively. This terminology emanates from the fact that each category is discretely collected in a plastic bag. As an alternative or in addition to bag collection, the exhaust is sampled continuously and analyzed at some interval, usually 30 seconds. This is known as modal analysis. The cold transient phase is intended to incorporate the cold start. Of the 505 seconds of this bag, the first 15 seconds is used for free idle and the next 5 seconds is for idling in gear.

The standard temperature range of the FTP is 68-86°F. For lower temperatures, the FTP driving cycle is used and the changes in emissions form the basis for temperature correction factors. In contrast, as it becomes colder, the driver tends to extend the initial warm-up time and because the vehicle is stationary, these emissions must be isolated and considered separately.

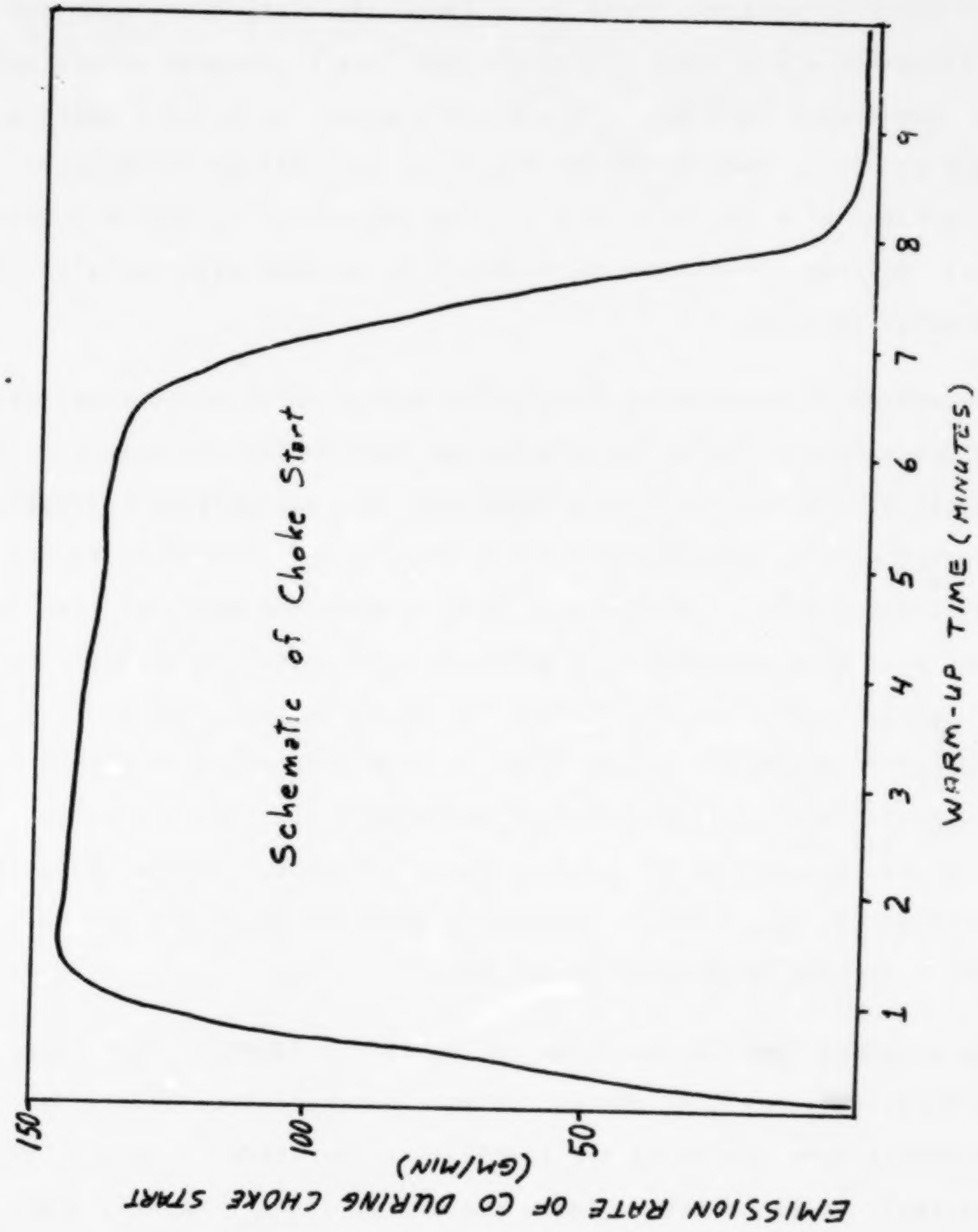

Schematic of Choke Start
EMISSION RATE OF CO DURING CHOKE START
(GM/MIN)
150
100
50
WARM-UP TIME (MINUTES)
1
2
3
4
5
6
7
8
9

FIGURE 1

Splitting Factors

Given the immense time and resources expanded by the EPA in developing, refining and updating emission factors it would be impractical to change their methodology. The FTP is the standard driving cycle test and also serves as a common base for determining urban driving fuel economy. Because of this, we have developed adjustment factors, referred to as "splitting factors" to incorporate the cold start. These are used to split the FTP emission factors between a stationary and mobile phase. A percentage of the emission factor is assigned to the transportation system (mobile phase) and a different percentage to the area where the trip originated (stationary phase).

Our "Four Bag Method" extends and isolate the cold start. In addition to the three bags of FTP, we have included an additional one, Bag 0, to collect the initial warm-up emmisions. A rigorous use of this method at standard FTP conditions would require the first 20 seconds to be collected in Bag 0 and the remaining 485 seconds as Bag 1. As a practical consideration, however, baseline data incorporates the entire 505 seconds in Bag 1.

For a specified low temperature, the FTP driving cycle is utilized to collect the three bags of data. This is repeated, utilizing Bag 0, at various warm-up times. For each of these, Bag 0 is filled utilizing the constant volume sampler (CVS) to include the start-up and free idle emissions. Immediately after the end of the specified idle period, the FTP is commenced without shutting off the engine.

Test Data

Data from two separate efforts were used to calculate the splitting factors. The EPA Motor Vehicle Emissions Laboratory (MVEL) in Ann Arbor, Michigan (2) tested three vehicles at our request and the Department of Energy (DOE) was funded at our suggestion by the EPA Cold Climate Research Program (through the EPA Environmental Research Laboratory in Corvallis, Oregon) to test seven vehicles. (3) The ten vehicles are described in Table 1.

The test scenario consisted of allowing the vehicles to soak at 20°F for a sufficient length of time to allow the lubrication oil to reach that temperature. Experience indicates that oil is the last component to cool to the test temperature. Three separate idle warm-up periods were 2, 5 and 10 minutes for the MVEL study 2, 6 and 10 minutes for the DOE study. The raw data is in Table 2.

Since DOE used a 6-minute warm-up as an intermediate time and EPA used 5 minutes, interpolation was necessary to combine the data. Because the bulk of the date used a 6-minute warm-up, the EPA data was adjusted. The 5-minute Bag 0 emissions were adjusted by calculating the rate of change in Bag 0 between the 5-minute and 10-minute tests and adding the 1-minute increment to the 5-minute data. The 5-minute Bag 1 emissions were adjusted similarly using the Bag 1 data except the increment was subtracted. The new data is also in Table 2.

Calculation of Splitting Factors

In all cases, the FTP emissions at 20°F is the basis of comparison for this study and the resultant factors are for that temperature.

VEHICLES TESTED TO CALCULATE SPLITTING FACTORS

Vehicle	Year	Engine Size	Number of Cylinders
EPA Test Vehicles			
Chevrolet Nova	1977	250 CID/4.1 liter	6
Ford Pinto (California)	1978	140 CID/2.3 liter	4
Ford LTD	1978	302 CID/4.9 liter	8
DOE Test Vehicles			
BMW 5.28i (3-way catalyst)	1979	170 CID/2.8 liter	4
Dodge Challenger	1979	98 CID/1.6 liter	4
Honda Accord	1979	107 CID/1.75 liter	4
Plymouth Volare	1980	225 CID/3.7 liter	6
Mercury Bobcat	1980	140 CID/2.3 liter	4
GMC truck	1980	350 CID/5.7 liter	8
Ford truck	1980	300 CID/4.9 liter	8

TABLE 1

CARBON MONOXIDE EMISSIONS DATA -- FOUR BAG METHOD (RAW DATA)

	TEMP	WARM-UP TIME	BAG 0	BAG 1	BAG 2	BAG 3
1			1979 HONDA ACCORD			
	75			52.70	12.80	15.80
	20			249.70	7.80	11.50
	20	2	102.70	76.40	8.20	11.40
	20	6	199.10	28.40	8.70	13.80
	20	10	250.30	15.00	7.50	11.00
2			1980 PLYMOUTH VOLARE			
	75			84.60	0.60	13.70
	20			819.70	0.80	1.50
	20	2	209.10	782.60	0.80	1.40
	20	6	666.40	191.60	0.40	1.10
	20	10	957.20	0.38	0.40	0.80
3			1979 BMW 5.28i			
	75			28.40	3.70	4.30
	20			242.20	4.70	5.60
	20	2	194.40	44.90	5.10	5.20
	20	6	212.40	7.50	4.70	5.90
	20	10	217.70	5.60	4.60	5.30
4			1980 FORD LIGHT DUTY TRUCK			
	75			78.80	0.20	1.20
	20			446.60	0.50	0.80
	20	2	292.50	185.30	0.40	0.50
	20	6	471.90	0.40	0.30	0.70
	20	10	462.90	0.20	0.30	0.90
5			1979 DODGE CHALLANGER			
	75			95.10	35.10	55.20
	20			216.30	39.80	67.00
	20	2	102.80	144.30	41.10	29.50
	20	6	240.20	86.80	42.50	36.90
	20	10	251.60	77.50	36.50	40.40
6			1980 GMC LIGHT DUTY TRUCK			
	75			106.50	6.00	17.20
	20			539.70	21.00	24.00
	20	2	135.80	242.50	3.60	12.90
	20	6	227.30	26.00	3.50	12.00
	20	10	231.00	11.80	1.80	10.60
7			1980 MERCURY BOBCAT			
	75			35.20	4.20	9.70
	20			414.70	3.40	3.20
	20	2	169.80	183.70	3.50	2.70
	20	6*	324.10	56.70	2.60	2.00
	20	10	421.90	3.40	2.30	1.70
8			1978 FORD LTD			
	75			113.69	5.95	46.23
	20			839.80	4.41	23.10
	20	2	86.94	574.99	5.71	
	20	5	622.59	134.34	8.41	
	20	6*	645.06	116.11	8.41	
	20	10	734.92	43.17	7.35	
9			1978 FORD PINTO			
	20			324.58	57.37	94.27
	20	2	79.37	198.63	25.28	
	20	5	240.17	85.79	36.55	
	20	6*	249.41	81.14		
	20	10	286.35	62.54	48.76	
10			1977 NOVA			
	20			346.59	58.84	19.73
	20	5	337.85	39.40	51.00	
	20	6*	350.45	35.66	51.00	

* DATA ADJUSTED TO REPRESENT 6-MINUTE WARM-UP.

TABLE 2

Since the Bag 0 emissions increase and the Bag 1 emissions decrease with increased warm-up time, the splitting factors are a function of warm-up time.

Stationary splitting factors are developed by comparing the warm-up time specific bag 0 emissions to the non-warm-up FTP Bag 1 emissions according to the following relationship.

$$SF_s(t) = \frac{\text{bag 0 (t)}}{\text{BAG 1 / 3.59 miles}}$$

Where SF_s = stationary splitting factor
Lower case letters denote 4 bag method
Upper case letters denote 3 bag method

For example, there were a total of 9 vehicles that had 2-minute warm-up data. The "fleet" average Bag 0 emissions were 152.60 grams and the 20°F baseline non-warm-up FTP Bag 1 average was 443.9 grams. The latter has to be converted to grams per mile in order for the ratio to be applied to the emission factors. Since Bag 1 emissions reflect a total distance of 3.59 miles, the baseline average becomes 123.67 grams per mile. The ratio, 1.23, is the stationary splitting factor for a 2-minute warm-up time at 20°F.

The mobile splitting factors are calculated by comparing the sum of Bag 1 and Bag 2 emissions that occur after a given warm-up time to those measured during the non-warm-up FTP at 20°F according to the following relationship.

$$SF_m(t) = \frac{\text{bag 1(t) + bag 2(t)}}{\text{BAG 1 + BAG 2}}$$

Where SF_m = mobile splitting factor

No adjustment is needed for miles of travel as both are in the same units. The fleet avearage Bag 1 and Bag 2 emissions during the non-warmup, 20°F, FTP was 463.85 grams. The 2-minute warm-up corresponding average is 280.78 grams. The ratio, 0.6053, is the mobile splitting factor for a 2-minute factor warm-up at 20°F.

Figure 2 depicts the stationary and mobile splitting factors as a function of time. The initial 20-second threshold (unity for the mobile phase and zero for the stationary phase) reflects the 20-second warm-up of the FTP. These curves were used to determine splitting factors for several other warm-up times and are listed in Table 3. Exponential curves were fitted to portions of these curves to facilitate computation of splitting factors.

Using the Splitting Factor

The EPA computer program, MOBILE2, is used to generate emission factors to which the splitting factors are applied. In this case, two emission factors are generated. One is equivalent to Bag 1 and is used with the mobile splitting factor. The three variables in MOBILE2 that assign the percent of the vehicles that are cold started, are used to obtain the desired factors. They are PCCO, PCHS, and PCCC and represent percent cold start (non-catalytic vehicles), percent hot start and percent cold start (catalytic vehicles), respectively. By assigning them values of 100.0, 0.0, and 100.0, respectively, the emission factor generated by MOBILE2 is Bag 1 only. By setting the three variables to 44.2, 55.8, and 44.2, MOBILE2 generates a Bag 1 plus Bag 2 emission factor. Multiplying each emission by its corresponding splitting factors produces an

WARM-UP TIME	SPLITTING FACTORS STATIONARY PHASE	 MOBILE PHASE
20 seconds (FTP)	0.00	1.00
0.5 minutes	0.18	0.94
1.0 "	0.57	0.82
1.5 "	0.90	0.70
2.0 "	1.23	0.61
2.5 "	1.48	0.52
3.0 "	1.74	0.45
3.5 "	1.97	0.40
4.0 "	2.20	0.34
4.5 "	2.40	0.28
5.0 "	2.60	0.25
5.5 "	2.76	0.20
6.0 "	2.90	0.17
6.5 "	3.02	0.16
7.0 "	3.10	0.14
7.5 "	3.17	0.13
8.0 "	3.24	0.12
8.5 "	3.29	0.11
9.0 "	3.34	0.10
9.5 "	3.39	0.09
10.0 "	3.43	0.08

TABLE 3

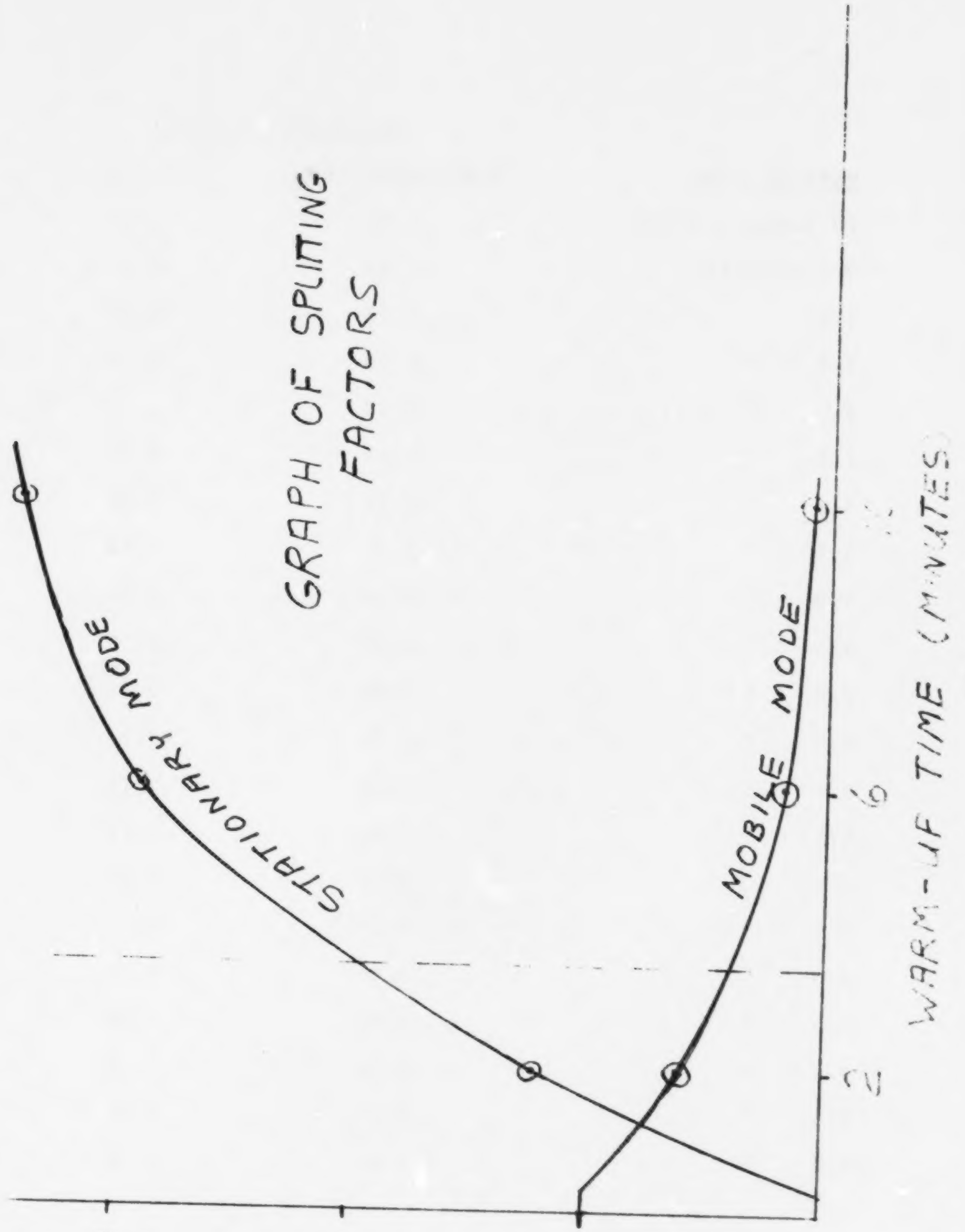

GRAPH OF SPLITTING FACTORS
SPLITTING FACTOR
3
2
1
STATIONARY MODE
MOBILE MODE
2
6
8
WARM-UP TIME (MINUTES)

FIGURE [illegible]

emission factor for each operational mode as shown in the following formula.

$$\text{Total Emissions} = SF_s(t) \times \text{Origins} \times EMF_1 + SF_m(t) \times VMT \times EMF_{1+2}$$

EMF_1 = Emission Factor for Bag 1

EMF_{1+2} = Emission Factor for Bag 1 and 2

For the development of splitting factors, Bag 3 emissions were not used for three reasons. It is the consensus of all involved with this work that Bag 3 emissions would not be affected by Bag 0 warm-up time, EPA-MVEL suggested excluding Bag 3 (4) and because of cost, this Bag was not collected for each warm-up time by EPA. Our initial approach was to weight Bag 1 and Bag 3 by 0.57 and 0.43, respectively and these plus Bag 2 would be divided by 7.5 miles to compute a grams per mile for a given warm-up time. This would serve as the basis for both the stationary and mobile splitting factors. Since this is essentially a feasibility study, EPA's suggested approach will suffice.

Driver Characteristics

The length of time a driver idles before driving is a crucial variable as indicated in Figure 2. It determines how much of the total emissions are from the cold start. In addition, the longer the vehicle is idled, the lower the driving emissions are. Warm-up time can vary with trip purposes. For example, a driver preparing to go to work may start the vehicle in the morning and allow it to warm up as he does his last-minute preparations to leave for work, such as scraping ice and/or snow from the windows. It is not uncommon for a driver to go back into his residence after starting the vehicle. In contrast, the afternoon work-to-home trip would be shorter due to the desire to get home. Shopping trips would be shorter still due to a short engine off period between trips.

In order to investigate driver tendencies, a questionnaire was prepared and distributed to 500 drivers having their vehicles tested at the Anchorage Free Emissions Control Test (AFECT) in the winter of 1979-1980. AFECT is a voluntary vehicle inspection program that was designed as a public awareness effort and to gather data on the degree of stringency needed for an Inspection and Maintenance (I/M) program.

The questions asked the length of time the driver warms the vehicle prior to initial movement of the vehicle. Responses were sought for different trip types (i.e., to work, to home and shopping). An analysis of the responses is depicted in Figure 4. The data was plotted on log-probability paper with the ordinate being the number of minutes of vehicle warm-up. The abscissa represents the percent of the respondents that warmed-up their vehicles at or longer than the time specified. The graphs show that warm-up time varies from individual to individual and with trip type. The 50th percentile values, selected to represent the mean warm-up time, are 3.5, 2.0, and 0.7 minutes for to work, to home and shopping trips, respectively.

Test Case One: Sand Lake

To illustrate the effect of this new approach, a small residential area in Anchorage was modeled. This area, Sand Lake, was chosen because there are only two roads providing access to the area. The access roads are labeled A and B and the area was over-layed with a

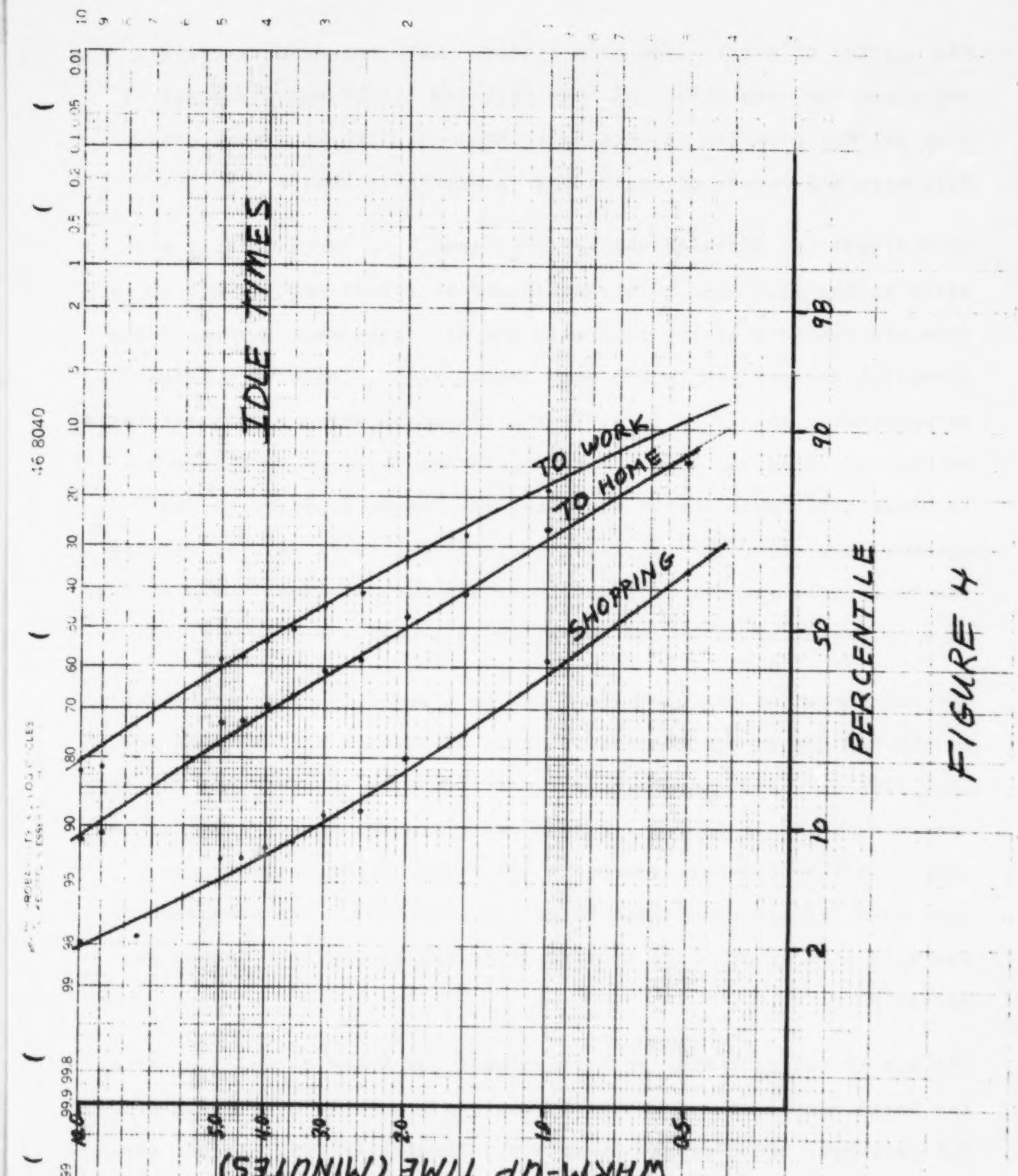

IDLE TIMES
TO WORK
TO HOME
SHOPPING
PERCENTILE
98
90
50
10
2
WARM-UP TIME (MINUTES)
10.0
5.0
4.0
3.0
2.0
1.0
0.5
46 8040

FIGURE 4

one quarter mile-on-a-side grid system. Only the major arterials are shown for resolution. A 1980 "housing stock" map was acquired from the Municipality of Anchorage (MOA) Planning Department to determine the number of residences in each grid square.

To estimate the distance the vehicles travel, a route map was prepared on the same grid. Intra-grid square travel was assumed to be from the centroid of the square to the side that best described the direction the vehicles would most likely take. These were drawn perpendicular to a side in all but a few cases where a definite route through the grid was known. This route map is shown in Figure 5. In those cases when a path was along the common boundary of two squares, the vehicle miles traveled (VMT) was split equally between the two. Once the paths to the arterials were plotted it was necessary to decide which of the two major arterials they would follow.

The intersections marked A and B can be assumed to offer equal desire to the residences of the area in terms of service to the Anchorage Bowl. The path a driver takes was determined by the shortest distance from a centroid to A or B. Once these distances were determined, the number of vehicles that reached A and B was checked against the peak hour traffic counts for those two arterials. The agreement was within 1% error. The traffic distribution was then judged to be valid.

The sum of the peak hour traffic volumes (at A and B) was divided by the total number of households in the study area to give a factor of 0.6 peak hour vehicles per household. Through traffic was not considered. This factor was applied to the number of households in

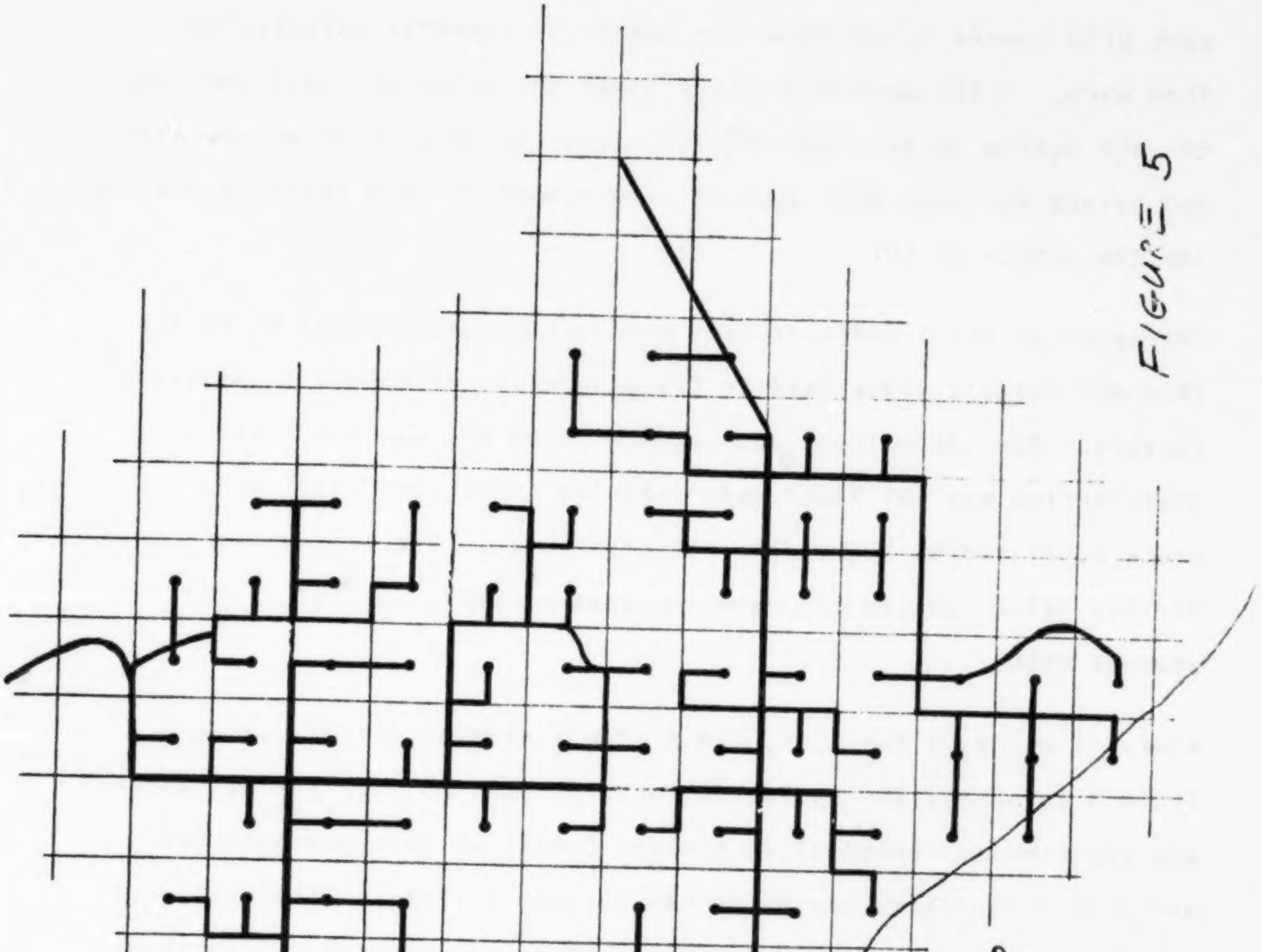


FIGURE 5

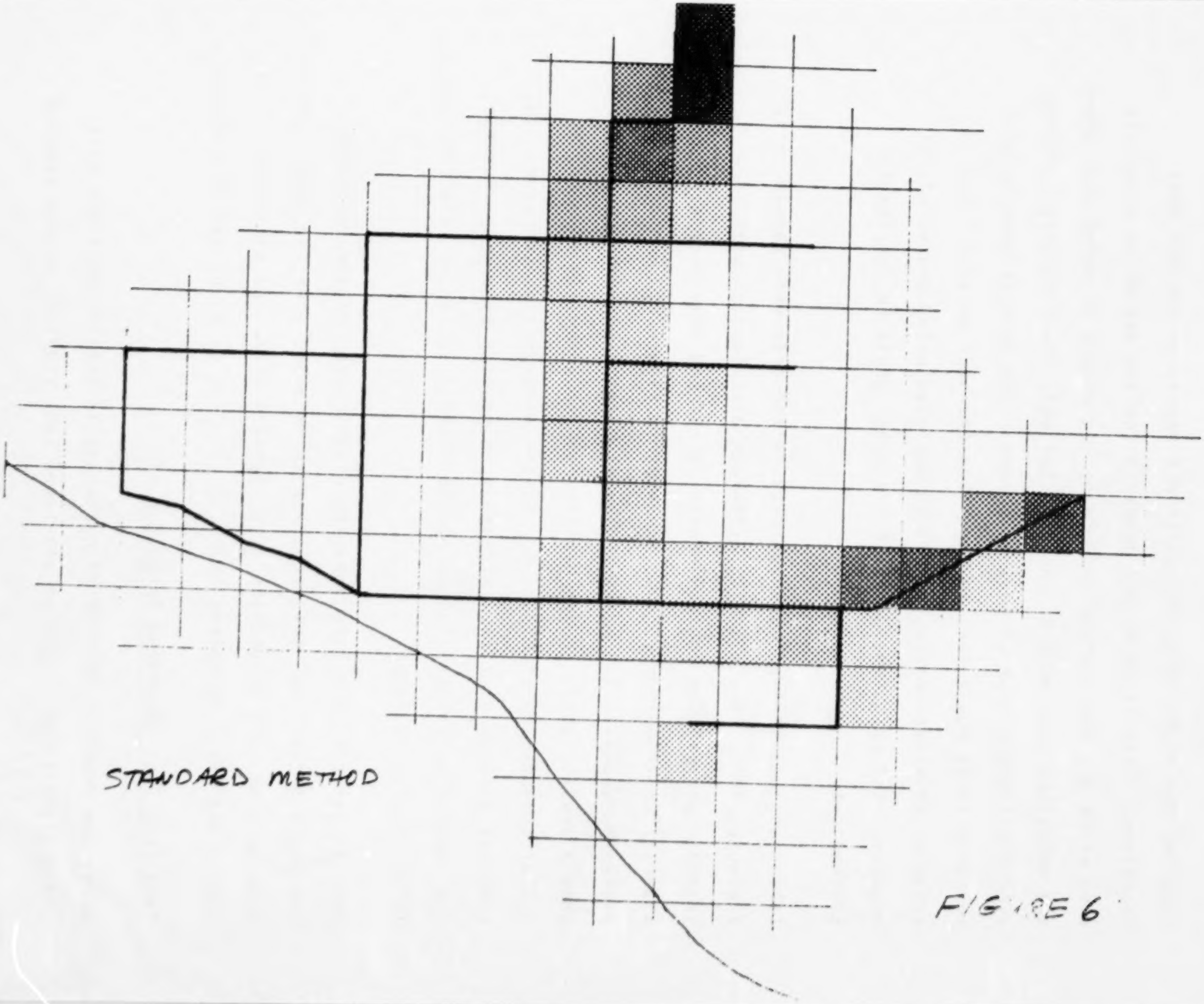
SHORTEST ROUTE MAP

each grid square to estimate the number of vehicles originating from each. These were multiplied times the miles of route assigned to each square to give the VMT for each. At this point we now have two values for each grid square: The number of cold starting vehicles and the number of VMT.

The speed of all traffic in this mini-system was assumed to be the 19.6 MPH default value used in the generation of Mobile 2 emissions factors. The temperature was assumed to be 0°F and the traffic distribution was 65% light duty vehicles (LDV), 30% light duty truck (LDT) and 5% heavy duty vehicles (HDV). The latter was further split between 65% gasoline powered (HDG) and 35% diesel powered (HDD).

Analysis was made for 2, 4, and 6 minute warm-up periods using Table 3 to obtain the splitting factors. The 20°F splitting factors are expected to represent an average condition that accounts for vehicles in garages (heated or non-heated) and those with engine block pre-heating systems as well as those unprotected. From these, factors, the stationary and mobile emission factors were calculated. In each case, the stationary phase emission factor was multiplied by the number of cold starts (trip origins) in the square and the mobile phase emission factor was multiplied by the VMT in each square. The two emission estimates were then added together. This was done for each warm-up time.

The normal method of multiplying the unaltered FTP emission factor times the VMT in each square was used as a reference and the resultant emission density distribution is depicted in Figure 6. As is



STANDARD METHOD

FIGURE 6

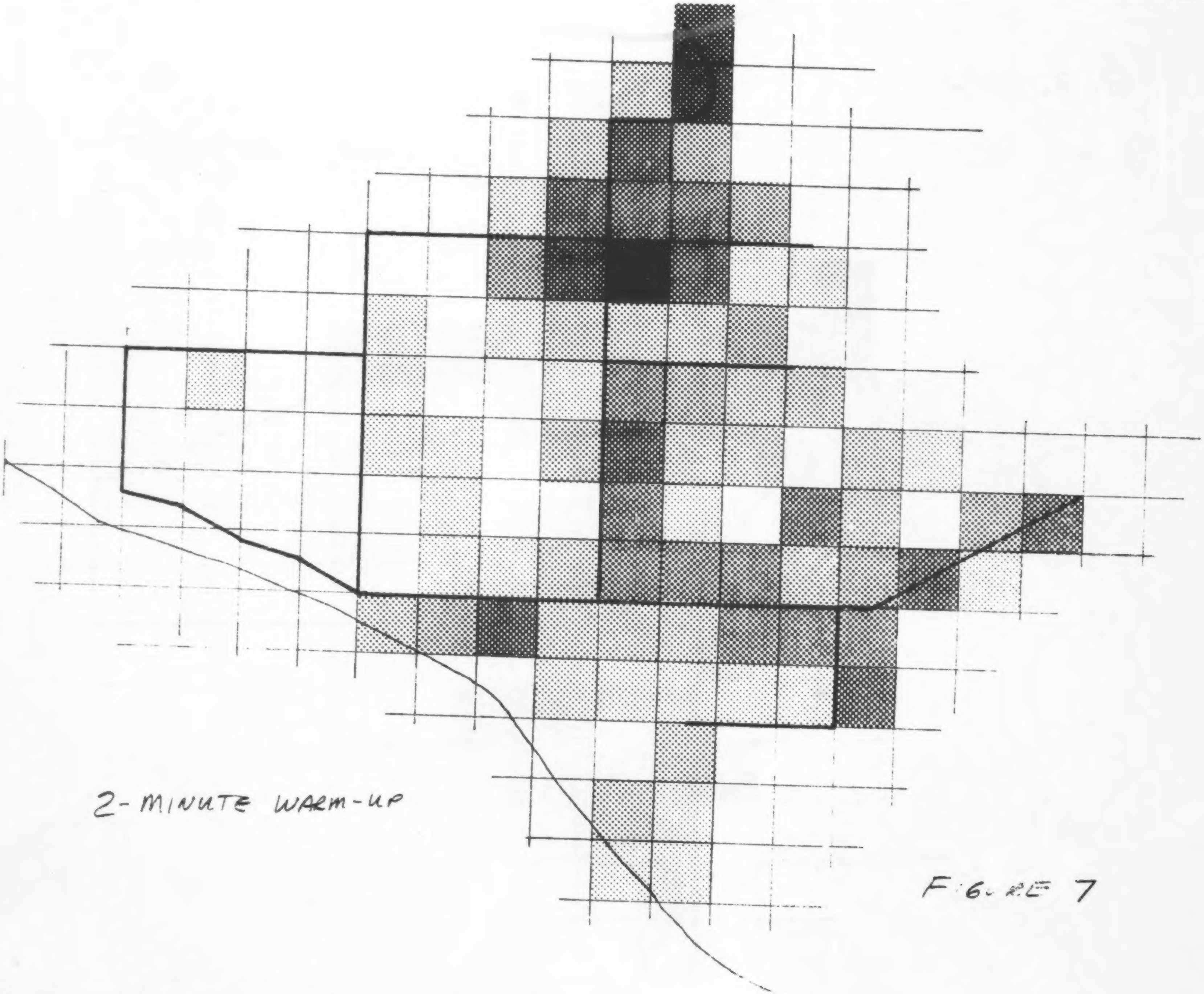
expected the highly traveled arterials represent the hot spot locations. This is certainly apparent for the two major arterials over which all the traffic must pass. It should be noted that there are emissions over much of the area but only those squares emitting over 5 kilograms/hour of CO were shaded. The optical-density of the shading is equivalent to the kilograms/hour emitted. For example, 70 kilograms/hour would be depicted using shades of 70% opacity. All emissions over 100 kilograms would be completely blacked out.

If one assumes that all the vehicles in the area were warmed-up for 2 minutes there is a slightly different distribution with more shading occurring in the residential areas and some decrease in major arterial contributions. This is shown in Figure 7. Figures 8 and 9 represent analysis for 4 and 6 minutes minutes of warm-ups. These show a drastic shift in the distribution of emissions from the normal methodology of Figure 6. As the warm-up time increases, the complete dominance of the cold start is readily apparent. Further, the increasing insignificance of the roadway system to total emissions is clearly illustrated.

One can see that not only does the distribution of the emissions change, but the total emissions for the modeled area increase with warm-up time. To illustrate this, Table 4 lists the stationary, mobile and total emissions for 1, 2, 3, 3.5, 4, 5, 6, and 10 minutes.

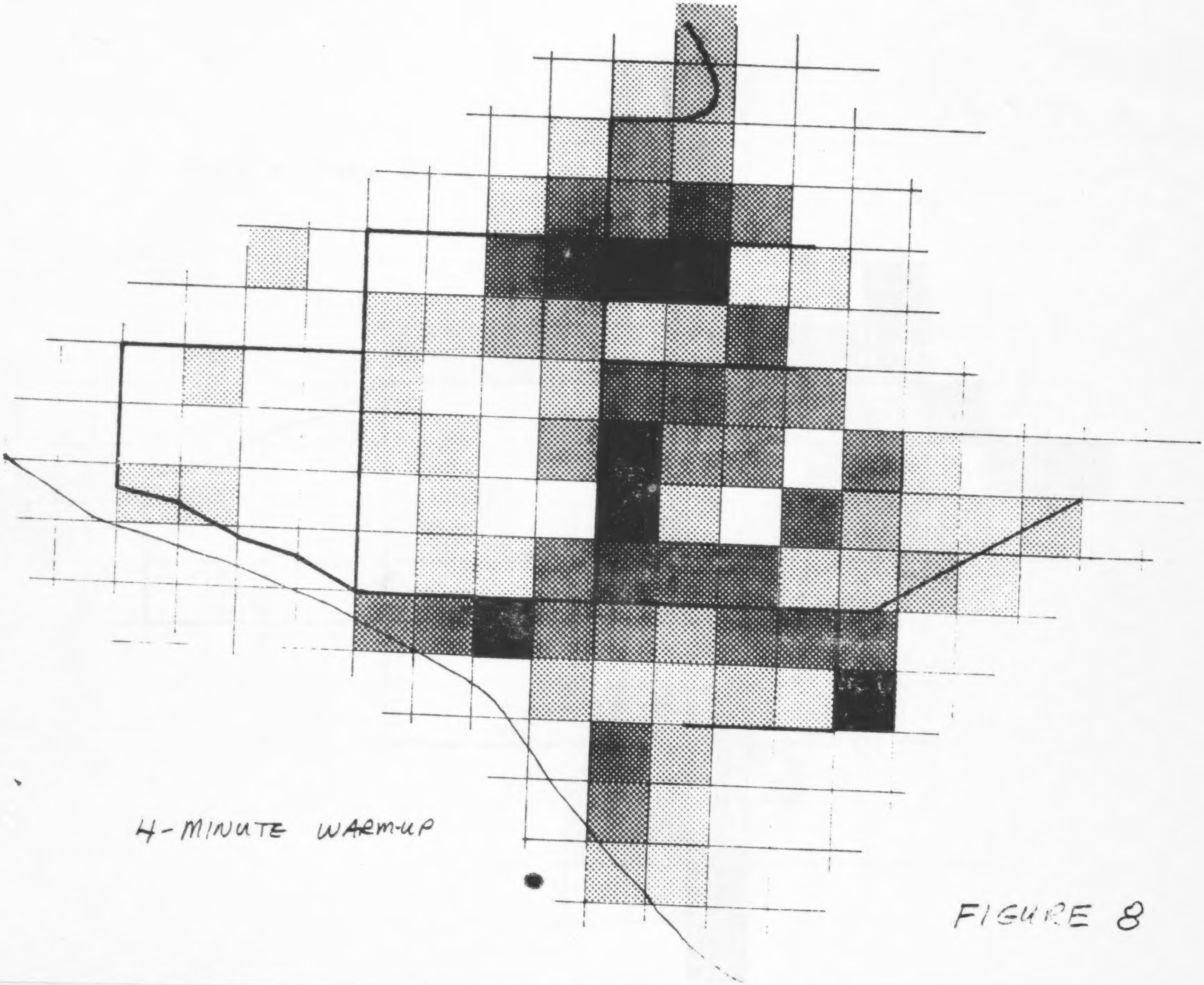
Test Case Two: Downtown Anchorage

Since the downtown section of Anchorage is considered a hot spot and a significant origin of afternoon peak traffic, it was decided



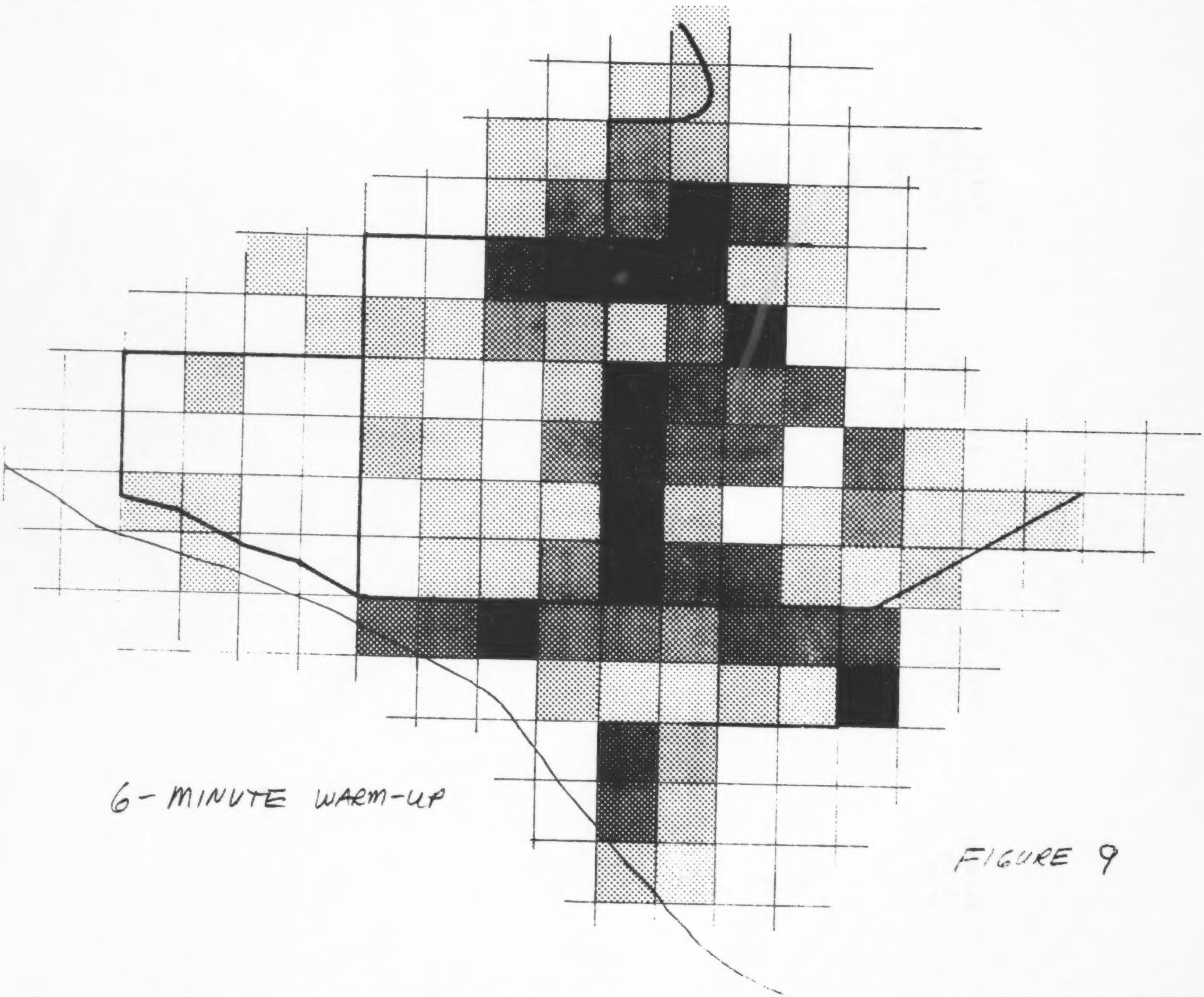
2-MINUTE WARM-UP

FIGURE 7



4-MINUTE WARM-UP

FIGURE 8



6-MINUTE WARM-UP

FIGURE 9

SAND LAKE TEST CASE

Warmup Time (Min.)	Stationary Emissions (Kg. CO)	Mobile Emissions (Kg CO)	Total Emissions (Kg CO)
0		1358	1358
1	695	1114	1809
2	1501	829	2329
3	2124	624	2748
3.5	2404	538	2924
4	2664	462	3126
5	3133	333	3466
6	3539	231	3769
10	4185	109	4249

TABLE 4

to evaluate this area as above. Unless stated otherwise, the same assumptions apply. Some of the downtown parking is located on the roadway (curb parking), but the majority is located in parking lots or garages.

Traffic and parking data was taken from the 1979 Anchorage CBD circulation study (5). This will be referred to as the "parking study" throughout this report.

The average daily traffic (ADT) used was from the parking study. The year of record was 1976. As deduced in the parking study, a 4% per year increase was used (i.e., 112% of 1976 ADT for 1980). Also from the parking study, an 8% factor was used to convert the ADT to peak hour traffic volumes. Each street segment length was assumed to be 0.075 miles long. The product ot 1976 ADT, 112%, 8%, and 0.075 miles is the estimated vehicle miles traveled (VMT) for each street segment. Traffic common to two grid squares was equally divided between the two.

Off-street parking capacity was used directly from the parking study with no adjustment for the year. In those cases where two blocks were combined, half of the capacity was assigned to each. As per the parking study, a 40% parking space occupancy was assumed and all were assumed to empty out during the peak hour. All vehicles were assumed to be cold started except those in the heated parking garage. The average warm-up time was assumed to be two minutes. Forty percent on-street parking utilization was assumed.

Sets of histograms are used to depict the contribution of the stationary and mobile source as shown in Figure 10. The eight

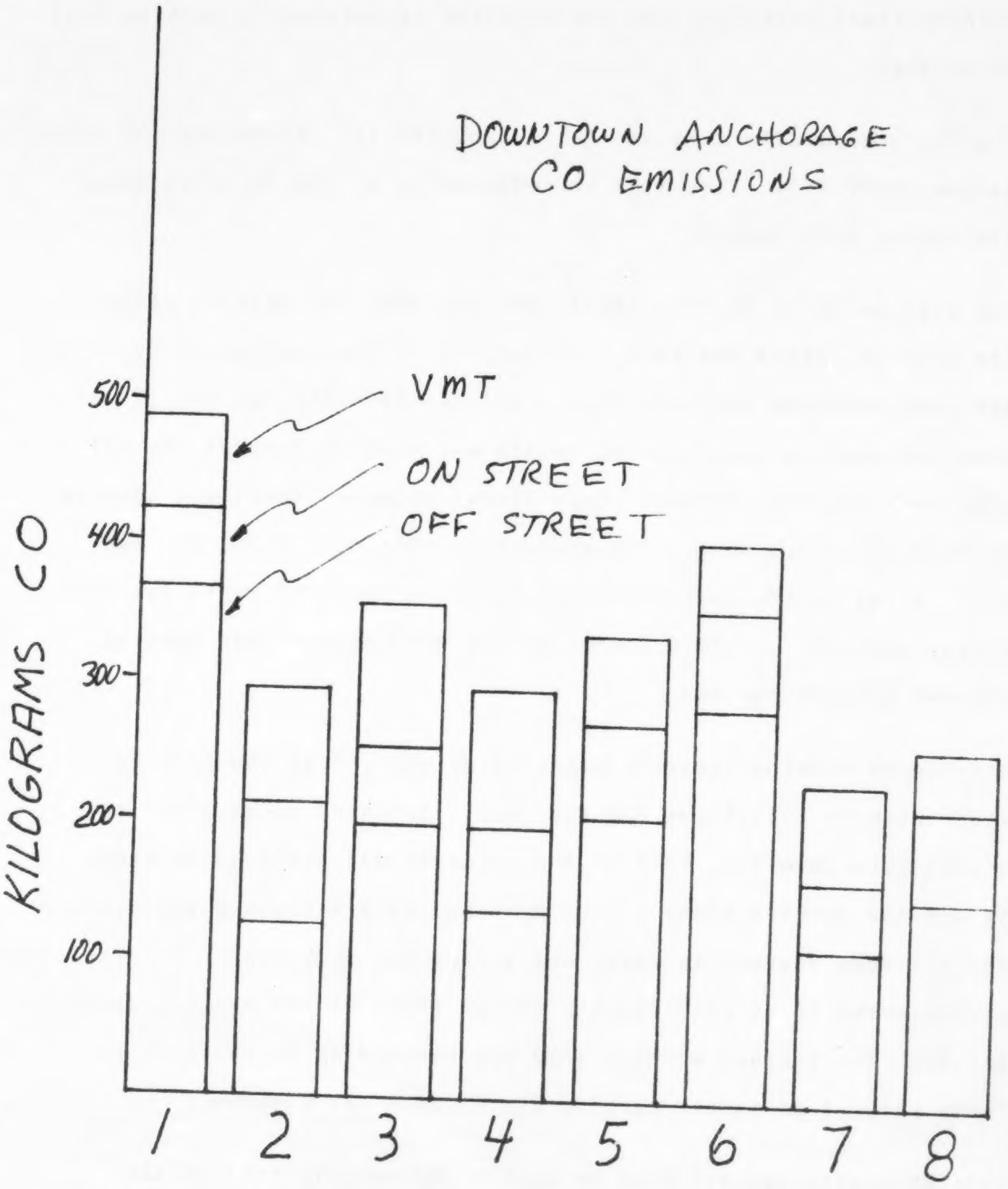

DOWNTOWN ANCHORAGE
CO EMISSIONS
KILOGRAMS CO
500
400
300
200
100
VMT
ON STREET
OFF STREET
1
2
3
4
5
6
7
8

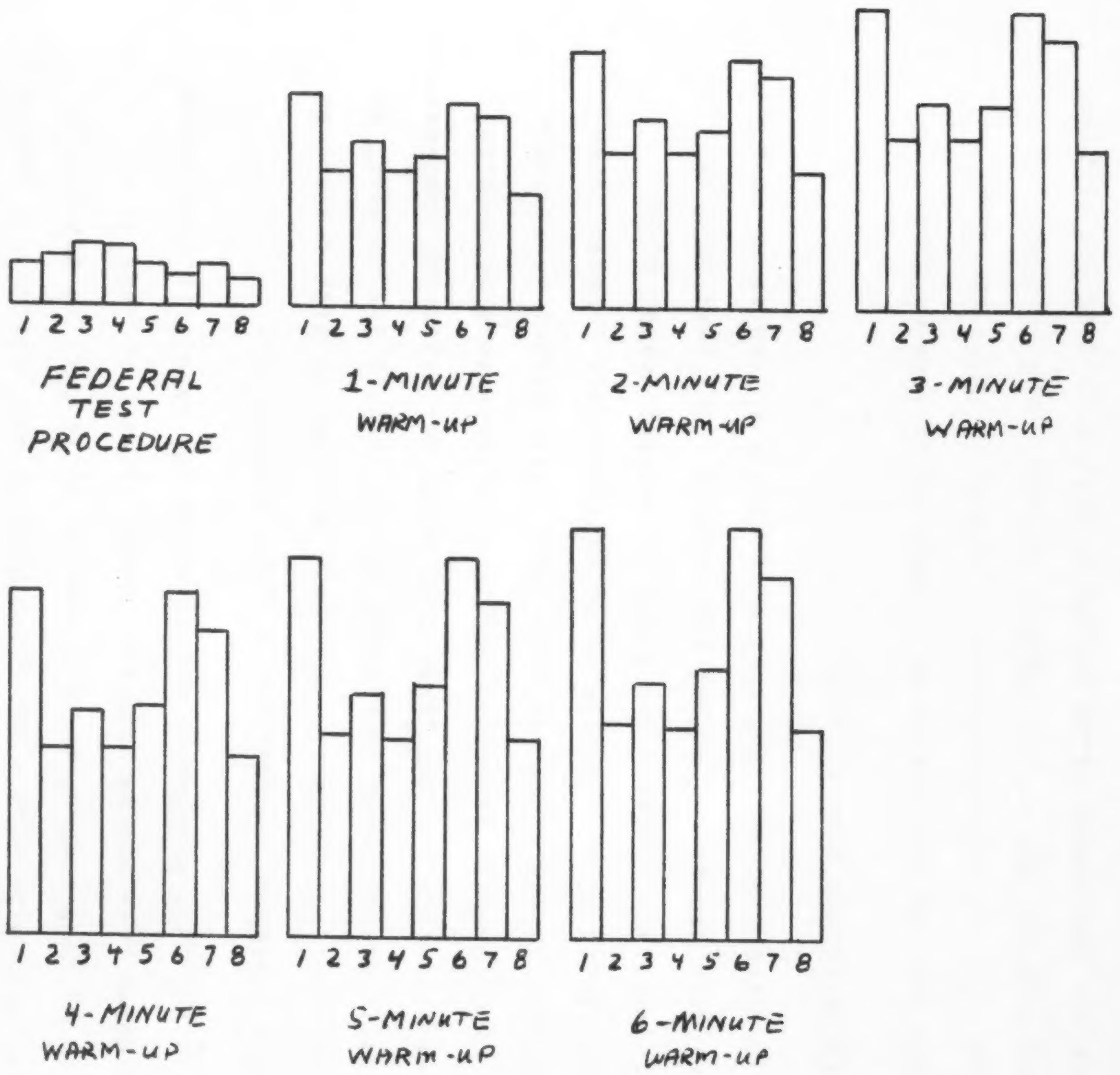
FIGURE 10

bars in each set correspond to the grid square one-quarter mile a side, each containing nine city blocks. A schematic is shown in Figure 11. The height of each component bar is equivalent to its contribution, hence, the total height is the total emissions. The bars are compounded (from bottom to top) by off-street parking, onstreet parking, and moving vehicle traffic. The influence of the cold start is readily apparent. Figure 12 shows the total emissions for the grid system as a function of warm-up time.

Temperature Versus Warm-up time

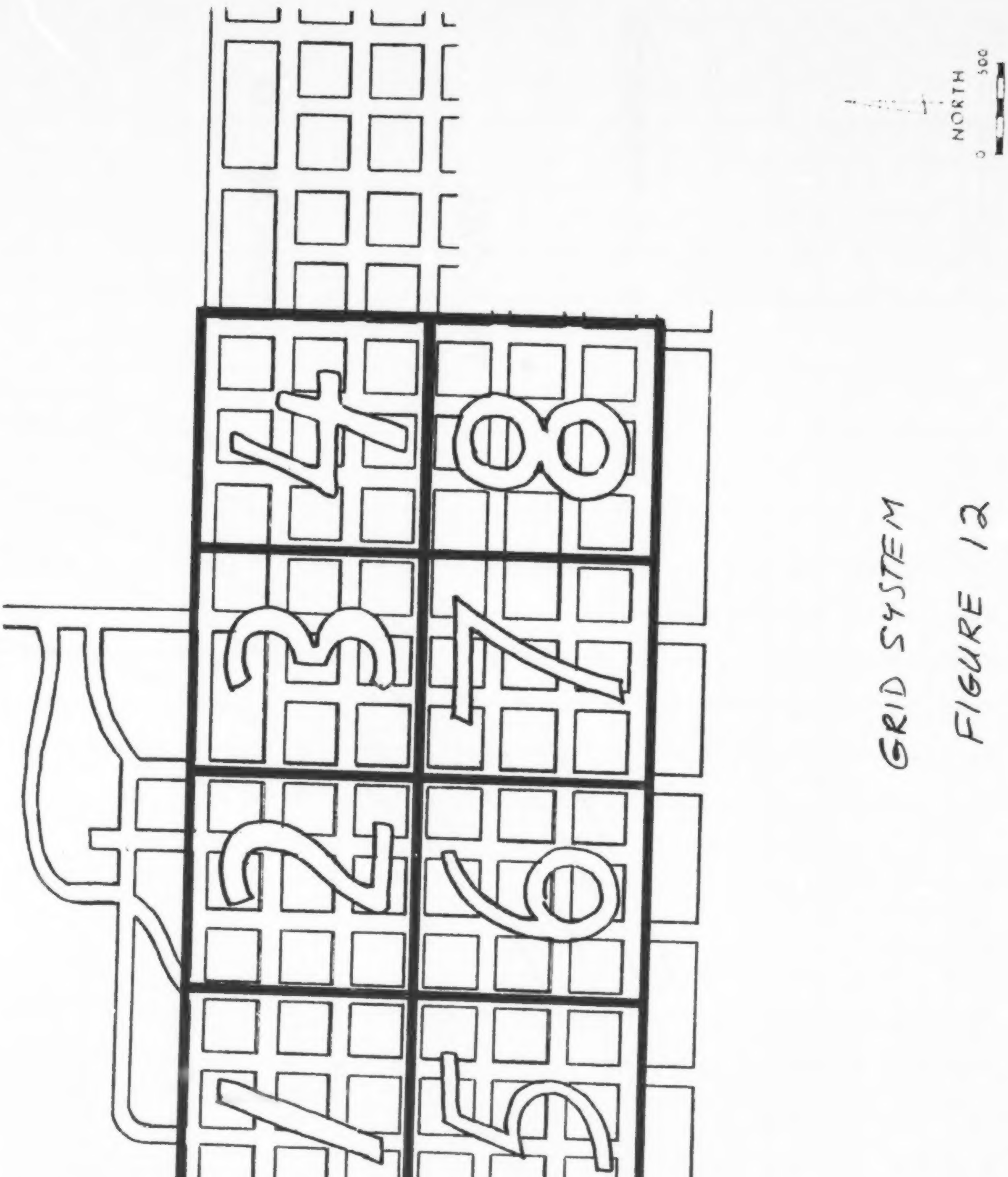
It was hypothesized that the length of time a driver warms up his vehicle would depend on ambient temperature . To test this, a questionnaire was prepared and given to drivers having their vehicles tested at the Vehicle Emissionns Analysis Program (VEAP) in Fairbanks in the winter of 1980-1981. This effort is similar to the AFECT program discussed earlier. Drivers were to specify their warm-up time for the three trip types for different temperatures. The results are depicted in Figures 13, 14, and 15 for to work, to home and shopping, respectively. This provides us with a means to calculate splitting factors for a given temperature.

By using the 50th percentile value curves for each trip type curves can be drawn that approximate the length of warm-up time as a function of temperature, the FTP time of 20 seconds is assumed to be coincident with 70°F. The relationships are depicted in Figure 16. Since MOBILE2 requires a temperature as input, this relationship could be used in that program to generate a warm-up time which is then used to generate splitting factors. Experimental curves were



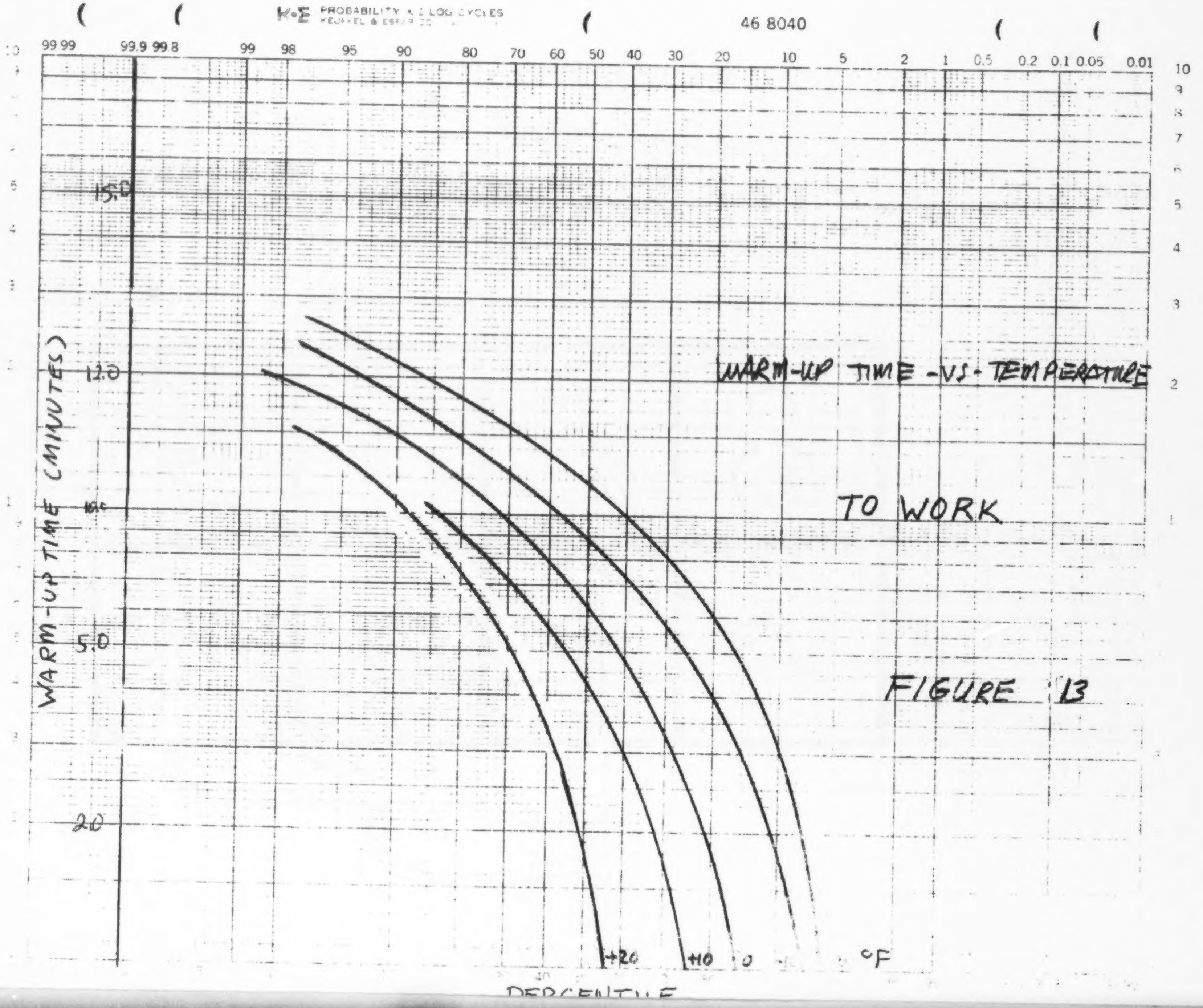
TOTAL CC EMISSIONS - VS - WARM-UP TIME

FIGURE 11


1
2
3
4
5
6
7
8
NORTH
0
500

GRID SYSTEM

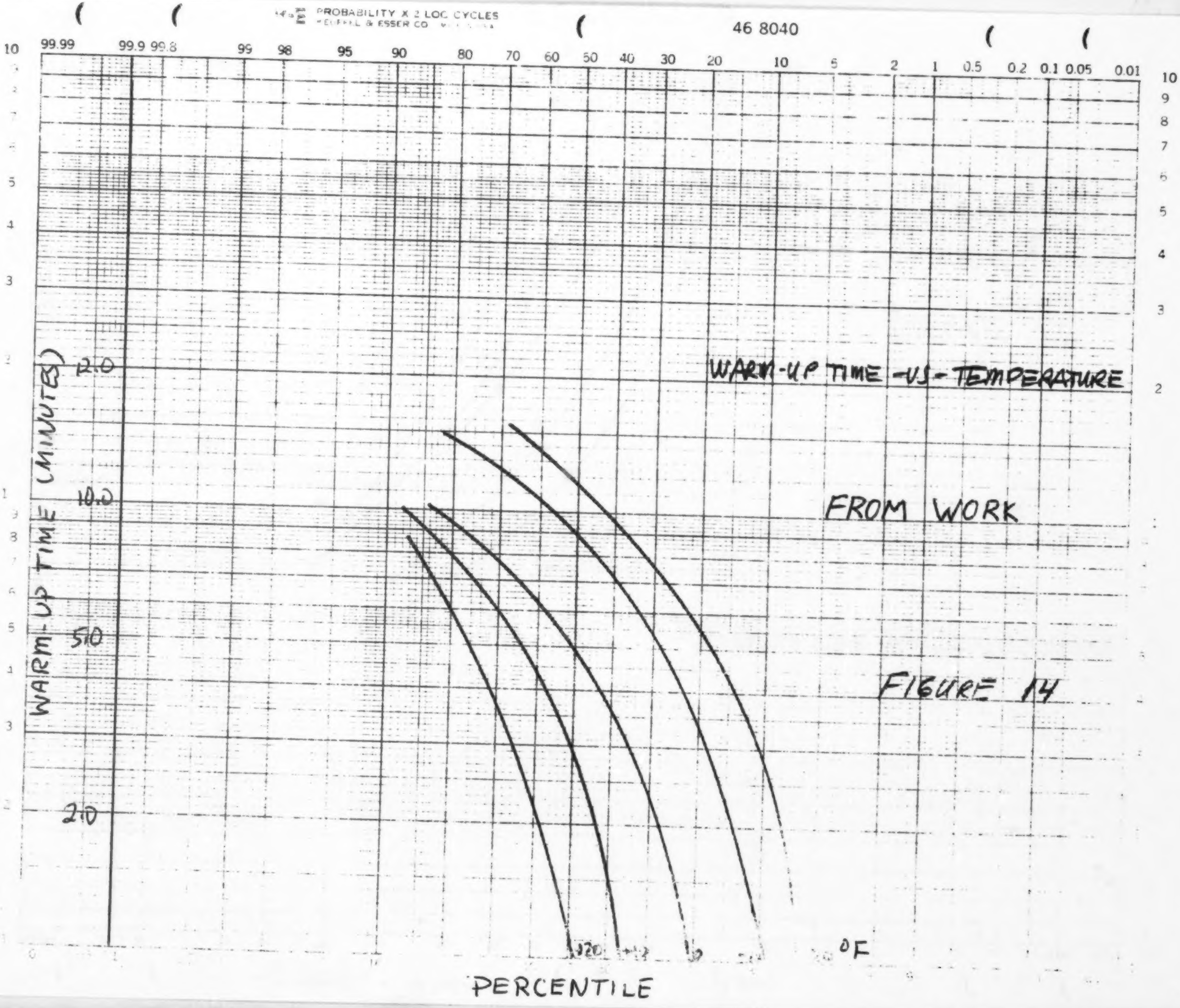
FIGURE 12



WARM-UP TIME -VS- TEMPERATURE

TO WORK

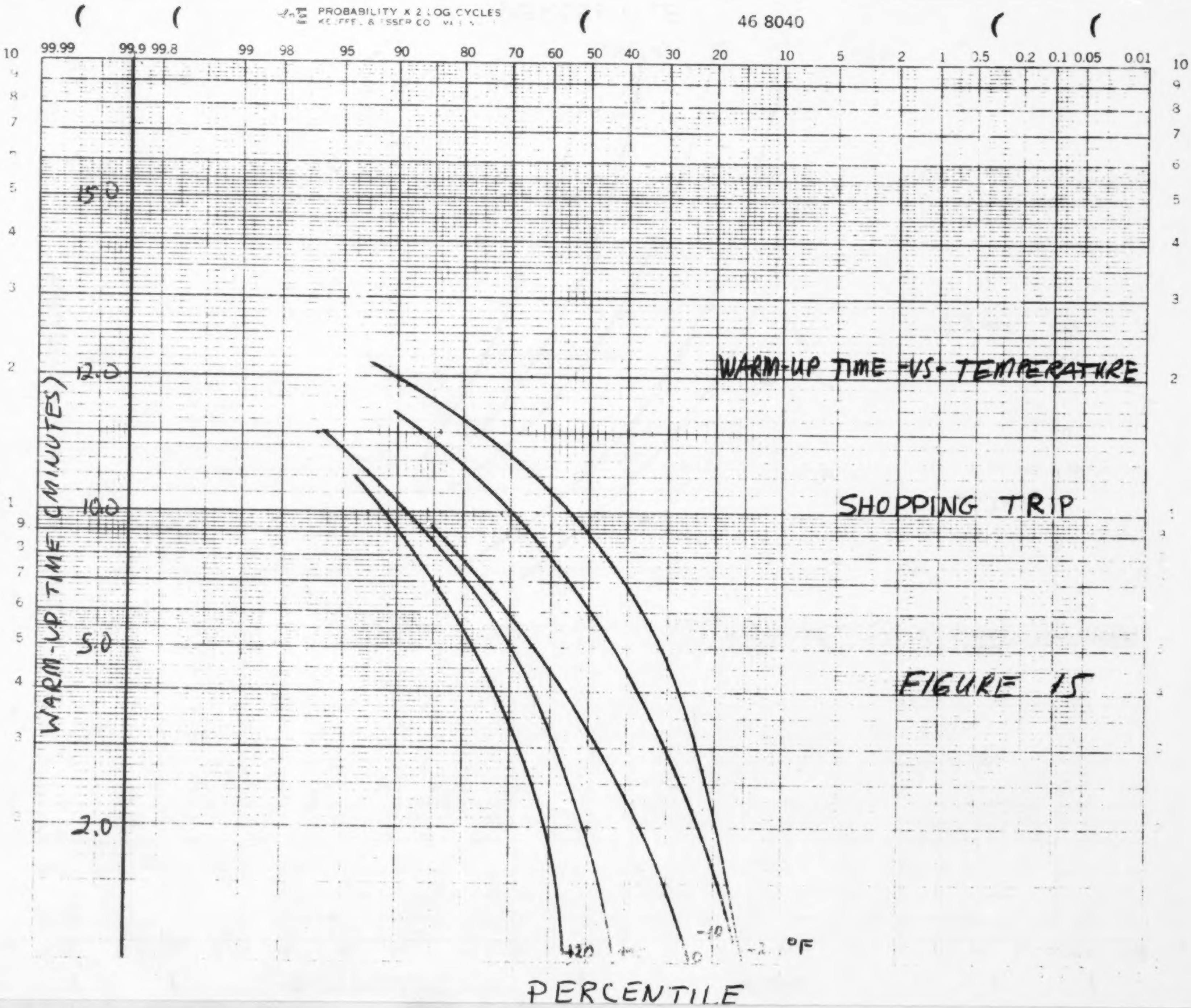
FIGURE 13



WARM-UP TIME -VS- TEMPERATURE

FROM WORK

FIGURE 14



WARM-UP TIME -VS- TEMPERATURE

SHOPPING TRIP

FIGURE 15

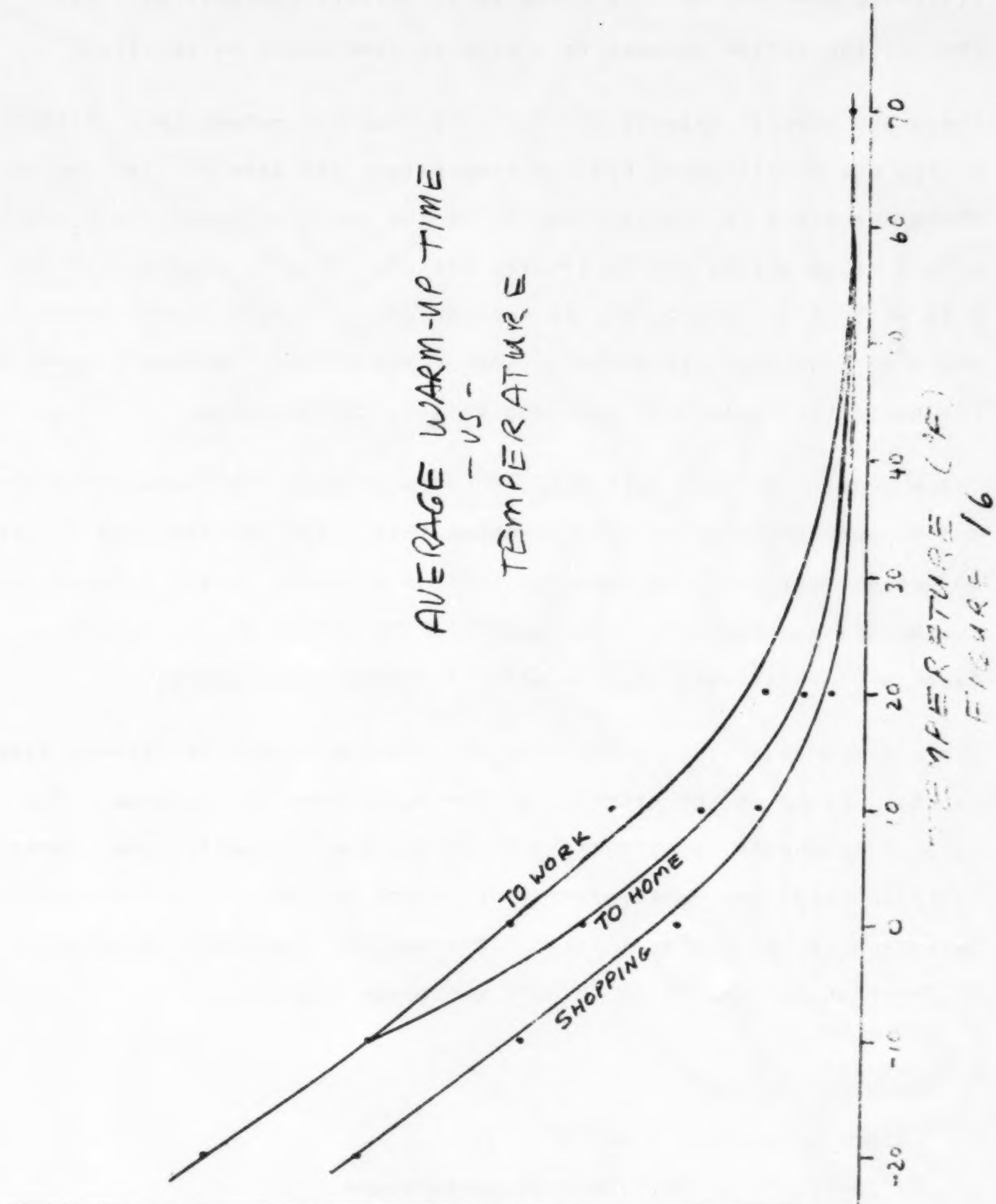

AVERAGE WARM-UP TIME
- VS -
TEMPERATURE
TO WORK
TO HOME
SHOPPING
WARM-UP TIME (MINUTES)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
TEMPERATURE (°F)
-20
-10
0
10
20
30
40
50
60
70

FIGURE 16

fitted to portions of this curve to facilitate computation. Of course, the option to specify a warm-up time would be retained.

There are several aspects of Figure 16 that are noteworthy. Principally, the relationship between temperature and warm-up time are those perceived by the respondents to the questionnaire. Such qualitative measurements can be greatly biased. Also by considering the 50th percentile, a bias may be introduced. A more rigorous process would be to weight the warm-up time by its effect. However, given the subjective nature of the data this is not required.

There appears to be a real difference in warm-up time between to home and to work trips above -10°F. Below that, they are the same. This indicates that the trip type may be less a factor at the extreme end of the scale. Further, it is possible the effect of the splitting factors diminish very rapidly above freezing temperatures.

There is no doubt that a limit to the average length of warm-up time exists. Based on the extremes of the questionnaire responses, the value is probably not greater that 30 minutes. Finally, the temperature/warm-up time relationships of Figure 16 reflects driver characteristics in Fairbanks, Alaska. This may not represent other areas of the country especially in more temperate regions.

Conclusions

1. Length of warm-up time is:
   - Inversely proportionsl to temperature
   - A function fo reason for the trip

2. As warm-up time increases:

    - Total emissions increase
    - Stationary mode component increases
    - Spatial distribution shifts to residential areas in morning and to commercial areas in the aftermoon
    - Contribution from roads decreases as background becomes a more important influence on measured concentrations

Further refinement of this method is underway. Additional test cases are available and data from an expanded fleet will be incorporated into the existing analysis.

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2. Private communication with T. Darlington of Motor Vehicles Emissions Laboratory, Environmental Protection Agency, Ann Arbor, Michigan, July 1980 and December 1980.

3. Koehler, D.E., "Cold Temperature Emission Factors," Bartlesville Energy Technology Center, U.S. Department of Energy, Bartleville, Oklahoma.

4. Private communication with Phil Lorang of Motor Vehicles Emission Laboratory, Environmental Protection Agency, Ann Arbor, Michigan, December 1980.

5. Anchorage CBD Parking and Traffic Circulation Study by DeLeuw, Cather and Company in association with Tryck, Nyman and Hayes, May 1979.

DIESELS
AND
AIR QUALITY

PRESENTED TO THE
NINTH ANNUAL NORTH AMERICAN
MOTOR VEHICLE EMISSIONS CONTROL CONFERENCE
BY GERALD L. GALLAGHER, PROGRAM DIRECTOR OF
MOBILE SOURCE PROGRAMS, AIR POLLUTION CONTROL DIVISION OF
THE COLORADO DEPARTMENT OF HEALTH

MAY 5-7, 1982

DIESELS AND COLORADO'S AIR QUALITY

INTRODUCTION

IN THE PAST, LIGHT DUTY DIESEL VEHICLES HAVE COMPRISED A RELATIVELY SMALL PERCENTAGE OF THE VEHICLE POPULATION IN THE UNITED STATES. HOWEVER, OVER THE NEXT 20 YEARS THE PRODUCTION AND SALE OF LIGHT AND HEAVY DUTY DIESEL VEHICLES ARE PROJECTED TO INCREASE SUBSTANTIALLY. A "BEST ESTIMATE" AT THIS TIME PREDICTS LIGHT DUTY DIESEL VEHICLES TO BE 25% OF THE VEHICLE POPULATION BY 1995. THIS PREPARATION WILL ADDRESS SOME OF THE AIR POLLUTION CONCERNS TO COLORADO FROM AN INCREASED DIESEL VEHICLE POPULATION.

DIESEL ENGINE OPERATION (O-1)

DIESEL ENGINES HAVE OPERATING PRINCIPLES MUCH DIFFERENT FROM SPARK-IGNITION (GASOLINE-TYPE) ENGINES. A DIESEL ENGINE DRAWS AIR THROUGH AN INDUCTION SYSTEM, HIGHLY COMPRESSES THE AIR IN THE ENGINE'S CYLINDERS AND THEN INJECTS A SMALL QUANTITY OF DIESEL FUEL INTO THE CYLINDERS TO CAUSE COMBUSTION TO TAKE PLACE. THE STRATIFIED CHARGE OF FUEL BURNS THROUGH AN AIR/FUEL RATIO BETWEEN 17 AND 100:1. SPARK IGNITION ENGINES, ON THE OTHER HAND, BURN A PREMIXED HOMOGENOUS CHARGE OF FUEL THROUGH AN AIR/FUEL RATIO BETWEEN 12 TO 17:1. BECAUSE OF THE STRATIFIED CHARGE OF A DIESEL ENGINE, THERE IS AN INFINITE RANGE OF FUEL/AIR MIXTURES; HOWEVER, THE BURNING STARTS AND CONTINUES WHERE THE FUEL/AIR MIXTURE IS CHEMICALLY CORRECT, ALTHOUGH SOME OF THE BURNING DOES OCCUR IN THE RICH AND LEAN AREAS.

THE COMPRESSION RATIO IN DIESEL ENGINES VARIES BETWEEN 14:1 TO 23:1. SPARK IGNITION ENGINES VARY FROM 8:1 TO 14:1.

THE FUELS USED IN DIESEL AND SPARK IGNITION ENGINES VARY SIGNIFICANTLY. DIESEL FUEL HAS A LOW RESISTANCE TO SPONTANEOUS COMBUSTION. A MEASURE OF HOW EASILY DIESEL FUEL WILL COMBUST SPONTANEOUSLY IS CALLED THE "CETANE NUMBER", WHILE THE "OCTANE NUMBER" FOR GASOLINE FUEL INDICATES THE OPPOSITE CHARACTERISTIC (RESISTANCE TO SPONTANEOUS COMBUSTION).

ANOTHER MAJOR DIFFERENCE BETWEEN DIESEL AND SPARK IGNITION ENGINES IS THE WAY POWER OUTPUT IS CONTROLLED. IN A DIESEL ENGINE, POWER IS CONTROLLED BY REGULATING THE FUEL QUANTITY, WHEREAS IN THE SPARK IGNITION IT IS CONTROLLED BY THROTTLING A FUEL/AIR MIXTURE, VIA THE CARBURETORS. THIS OVERHEAD SUMMARIZES THE DIFFERENCES BETWEEN DIESEL AND GASOLINE ENGINES.

DIESEL ENGINES ARE APPROXIMATELY 30% MORE EFFICIENT THAN A COMPARABLE GASOLINE ENGINE. AS PREVIOUSLY MENTIONED, DIESEL ENGINES HAVE HIGHER COMPRESSION RATIOS AND GENERALLY, ENGINE EFFICIENCIES INCREASE AS COMPRESSION RATIO IS INCREASED. ALSO, DIESEL ENGINES OPERATE AT MUCH LEANER AIR/FUEL RATIOS, CAUSING AN INCREASE IN FUEL ECONOMY.

THE PRIMARY FACTOR IN THE BETTER EFFICIENCY OF A DIESEL ENGINE IS THE LACK OF THROTTLING LOSSES. GASOLINE ENGINES ARE HEAVILY THROTTLED AT LIGHT LOADS, SINCE THE POWER OUTPUT IS REGULATED BY THE AMOUNT OF AIR PASSING THROUGH THE CARBURETOR. IN THE DIESEL ENGINE THE POWER OUTPUT IS REGULATED BY THE QUANTITY OF FUEL INJECTED; THEREFORE, THEY DO NOT INCUR THROTTLING AT LIGHT LOADS.

THE THROTTLING LOSSES IN A GASOLINE ENGINE ALSO EXPLAIN WHY SMALL GASOLINE ENGINES ARE MORE EFFICIENT AT A GIVEN LOAD THAN LARGER ENGINES.

DIESEL FUEL HAS APPROXIMATELY 15% MORE ENERGY PER UNIT VOLUME THAN GASOLINE. THEREFORE, ON A MILES PER GALLON BASIS, DIESEL ENGINES ARE ALREADY 15% BETTER THAN GASOLINE ENGINES. IN ACTUAL USE, THEY ARE LIKELY TO SHOW EVEN GREATER FUEL ECONOMY BENEFITS, SINCE THERE IS CONSIDERABLY LESS COLD START PENALTY (DIESEL ENGINES DO NOT HAVE CHOKES) AND PUMPING LOSSES. DIESEL AUTOMOBILES ARE MUCH MORE LIKELY TO EXCEED THEIR EPA CITY FUEL ECONOMY RATING THAN ARE GASOLINE-POWERED AUTOMOBILES.

DIESEL AIR POLLUTION CONCERNS

GASEOUS EMISSIONS RATES FROM LIGHT DUTY DIESELS (HYDROCARBONS AND CARBON MONOXIDE) ARE COMPARABLE TO OR OFTEN LESS THAN GASOLINE-POWERED VEHICLES. HOWEVER, DIESEL OXIDES OF NITROGEN EMISSIONS ARE HIGHER. NEARLY ALL LIGHT DUTY DIESEL VEHICLES ARE WAIVERED FROM THE THE CURRENT 1 GM/MI NOx STANDARD. THERE IS A MOVE NOW TO CHANGE THE OXIDES OF NITROGEN (NOx) STANDARD FROM 1 GM/MI TO 2 GM/MI, PARTIALLY TO ACCOMMODATE DIESELS. A PROJECTION OF THIS CHANGE ON AMBIENT NO_2 LEVELS IN THE DENVER METROPOLITAN AREA CAN BE SEEN IN THIS NEXT OVERHEAD. (O-2) SULPHUR DIOXIDE EMISSIONS FROM DIESEL ENGINES ARE ROUGHLY 10% GREATER THAN GASOLINE ENGINES. ANOTHER PROBLEM YET TO BE STUDIED IS THE EMISSIONS OF ALDEHYDES. THE MAIN POLLUTION CONCERN WITH DIESEL ENGINES IS THEIR PARTICULATE EMISSIONS WHICH ARE 30-100 TIMES GREATER THAN GASOLINE ENGINES, AS ILLUSTRATED BY THESE FILTER SAMPLES.

BEGINNING WITH 1982 MODELS, LIGHT DUTY DIESEL VEHICLES MUST MEET A PARTICULATE STANDARD OF .6 GM/MI. THE 1985 PARTICULATE (0-3) STANDARD WILL BE TIGHTENED TO .2 GM/MI. ALTHOUGH SOME VEHICLES ARE ALREADY CAPABLE OF MEETING THIS STANDARD, EPA IS EXPECTED TO EXTEND THIS DATE TO 1987. HOWEVER, SOME VEHICLES, PARTICULARLY LARGER MODELS, WILL NEED TECHNICAL MODIFICATIONS IN ORDER TO MEET THE .2 PARTICULATE STANDARD.

ANTICIPATED TECHNICAL CHANGES INCLUDE COMBUSTION CHAMBER AND FUEL INJECTOR MODIFICATIONS, ELECTRONIC FUEL INJECTOR PUMPS OR ELECTRONIC FUEL INJECTORS, TURBOCHARGING, AUTOMATIC ALTITUDE COMPENSATORS, WATER OR ALCOHOL INJECTION SYSTEMS AND TRAP OXIDIZERS. THE TRAP OXIDIZER IS THE DIESEL'S EQUIVALENT TO A GASOLINE VEHICLE'S CATALYTIC CONVERTER. THE PARTICULATE MATTER IS TRAPPED AND INCINERATED, USUALLY ON A PERIODIC BASIS WHEN THE TRAP BECOMES FULL.

HIGH ALTITUDE EFFECTS (0-4)

EMISSIONS FROM DIESEL VEHICLES INCREASE AT HIGH ALTITUDE, DUE TO A RICHENING OF THE AIR/FUEL RATIO. HYDROCARBON EMISSIONS INCREASE OVER 100%, CARBON MONOXIDE 75% AND PARTICULATE MATTER APPROXIMATELY 50%. THEREFORE, IT IS ANTICIPATED THAT THE AIR POLLUTION IMPACT OF INCREASED DIESELIZATION WILL BE GREATER IN HIGH ALTITUDE AREAS. (0-5) SOME MANUFACTURERS ARE CURRENTLY OFFERING DIESEL VEHICLES WITH TURBOCHARGERS AND AUTOMATIC ALTITUDE COMPENSATING DEVICES. NOT ONLY DOES THIS IMPROVE THE VEHICLE'S PERFORMANCE AT ALTITUDE, IT ALSO KEEPS THE EMISSION LEVELS AT OR CLOSE TO THE SEA LEVEL CERTIFICATION LEVELS.

THE DIESEL PARTICULATE

THE STRUCTURE OF A DIESEL PARTICULATE CONSISTS OF A SOLID CARBONACEOUS CORE ON WHICH A MYRIAD OF COMPOUNDS ABSORB. THESE COMPOUNDS HAVE BEEN SHOWN TO BE MUTAGENIC AND, THEREFORE, POSE A POTENTIAL CARCINOGENIC RISK. THE MUTAGENIC ACTIVITY IS ASSOCIATED WITH THE SOLUBLE ORGANIC FRACTION OF THE DIESEL PARTICULATE. SOME OF THE COMPOUNDS ARE KNOWN CARCINOGENS (I.E., BENZO(A)PYRENE). 80-90% (BY MASS) OF DIESEL PARTICLES ARE SMALLER THAN 1 MICRON, PLACING THEM IN THE HUMAN RESPIRATORY RANGE. (O-6) THEIR SMALL SIZE ALSO ALLOWS THE PARTICULATES TO REMAIN SUSPENDED IN THE ATMOSPHERE FOR A LONG TIME (SOME POTENTIALLY OVER ONE MONTH) FURTHER INCREASING THEIR RISK OF INHALATION. THIS CAN BE SEEN BY THE FALL RATE OF PARTICLES BASED ON SIZE.

IT IS NOT FULLY UNDERSTOOD AT THIS TIME WHAT HAPPENS TO THE DIESEL PARTICLE ONCE IN THE ATMOSPHERE. CARBON BLACK, VERY SIMILAR TO DIESEL PARTICLES, HAS A STRONG TENDENCY TO ABSORB OTHER COMPOUNDS (I.E., HYDROCARBONS, NO_2). DIESEL PARTICLES ARE SUSPECTED OF ACTING SIMILARLY. CONSEQUENTLY, "AGED" PARTICLES MAY BE MORE DANGEROUS THAN "FRESH" PARTICLES. THE PHOTOCHEMICAL ACTIVITIES OF DIESEL PARTICLES IS STILL SOMEWHAT AMBIGUOUS AND NEED FURTHER RESEARCH.

VISIBILITY IMPACTS

ELEMENTAL CARBON (SOOT) CONTRIBUTES APPROXIMATELY 40% TO THE VISIBILITY REDUCTION IN DENVER (THE WINTER "BROWN CLOUD"). DIESEL PARTICULATES CONTAIN LARGE PERCENTAGES OF ELEMENTAL CARBON. A DIESEL VEHICLE EMITS APPROXIMATELY 200% MORE LIGHT ABSORBING

ELEMENTAL CARBON THAN A COMPARABLE GASOLINE ENGINE. THE 1978 (O-7) STUDY CONDUCTED BY THE MOTOR VEHICLE MANUFACTURERS ASSOCIATION ESTIMATED THAT DIESEL VEHICLES (THEN PRIMARILY HEAVY DUTY TRUCKS) WERE RESPONSIBLE FOR APPROXIMATELY 20% OF THE ELEMENTAL CARBON AND 12% OF THE VISIBILITY REDUCTION IN DENVER. THE CONTRIBUTIONS BY DIESELS COULD BE GREATER THAN THESE FIGURES WOULD INDICATE AND OTHER STUDIES ARE CURRENTLY UNDERWAY TO DETERMINE THIS MORE EXACTLY.

IT IS PROJECTED THAT THE "BROWN CLOUD" WILL ONLY WORSEN WITH INCREASED DIESEL USE. THE DEGREE OF VISIBILITY DEGRADATION DEPENDS, OF COURSE, ON THE GROWTH RATE OF LIGHT DUTY DIESEL VEHICLES AND FUTURE PARTICULATE STANDARDS AND IN-USE PARTICULATE LEVELS OF DIESELS OPERATED AT DENVER'S HIGH ALTITUDE AND CONDITIONS WHICH CAUSE (O-8) EXCESSIVE SMOKE FROM DIESELS. A NATIONAL ACADEMY OF SCIENCE STUDY INDICATES THE POSSIBILITY OF A FURTHER 50% DEGRADATION IN (O-9) VISIBILITY IN DENVER BY 1995, WHEN THE NUMBER OF LIGHT DUTY DIESEL VEHICLES IS PROJECTED TO REACH 25% OF THE TOTAL VEHICLE POPULATION. ESTIMATES BY RADIAN CORPORATION AND THE COLORADO DEPARTMENT OF HEALTH YIELD POTENTIAL REDUCTIONS IN THE 20-60% RANGE. PRELIMINARY FINDINGS FROM THE NATIONAL CENTER FOR ATMOSPHERIC RESEARCH, IN BOULDER, COLORADO, INDICATE THAT THE VISIBILITY PROBLEM CAN BE RESEARCHED BY EVALUATING THE OPTICAL EXTINCTION, POLLUTANT AND VEHICLE TYPE, AS SHOWN ON THE FOLLOWING OVERHEADS. (O-10, O-11, O-12)

COLORADO DEPARTMENT OF HEALTH DIESEL STUDIES

IN LIGHT OF HEALTH AND VISIBILITY CONCERNS, EXTENSIVE RESEARCH EFFORTS HAVE BEEN LAUNCHED WORLDWIDE ON DIESEL EMISSIONS. THE COLORADO DEPARTMENT OF HEALTH (CDH) IS CURRENTLY INVOLVED IN SEVERAL STUDIES TO ASSESS THE CURRENT AND FUTURE IMPACT OF DIESELS ON COLORADO'S AIR QUALITY. COLORADO DEPARTMENT OF HEALTH DIESEL EMISSIONS ACTIVITIES CAN BE DEFINED BY THE FOLLOWING:

A. RADIAN STUDY - COLORADO DEPARTMENT OF HEALTH CONTRACTED WITH RADIAN CORPORATION TO CONDUCT A LITERATURE REVIEW OF DIESEL EMISSIONS AND AN ANALYSIS OF POTENTIAL DIESEL PARTICULATE CONTROL STRATEGIES AVAILABLE TO COLORADO. SUGGESTED CONTROL STRATEGIES INCLUDED A DIESEL I/M PROGRAM, REGULATING DIESEL FUEL PARAMETERS WHICH AFFECT EMISSIONS (I.E., 90% DISTILLATION TEMPERATURE, AROMATIC CONTENT, ADDITIVES, WATER CONTENT) LIMITING SALES OF DIESELS, AMONG OTHER POTENTIAL CONTROL STRATEGIES. THIS STUDY WAS COMPLETED DECEMBER 1, 1981. EXECUTIVE SUMMARIES ARE AVAILABLE FROM THE MOBILE SOURCES SECTION, AIR POLLUTION CONTROL DIVISION, COLORADO DEPARTMENT OF HEALTH.

B. HIGH ALTITUDE DIESEL VEHICLE EMISSION FACTORS

TESTING OF DIESEL VEHICLES AT HIGH ALTITUDE IS CURRENTLY BEING PLANNED. EMISSION FACTORS FROM THESE STUDIES WOULD BE USEFUL IN SOURCE APPORTIONMENT OF THE "BROWN CLOUD" STUDY AND FOR PROJECTING THE FUTURE IMPACTS OF DIESELIZATION. AN EVALUATION OF DIESEL VEHICLE TESTING NEEDS IS AVAILABLE.

C. NCAR STUDY

THE NATIONAL CENTER FOR ATMOSPHERIC RESEARCH, BOULDER, COLORADO, UNDER CONTRACT TO THE COLORADO DEPARTMENT OF HEALTH, IS CONDUCTING AN IN DEPTH ANALYSIS OF THE IMPACT OF DIESELIZATION ON VISIBILITY IN THE DENVER METROPOLITAN AREA. HIGH ALTITUDE DIESEL EMISSIONS FROM VEHICLE TESTING, INFORMATION FROM THE RADIAN STUDY, EPA DATA FROM THE "BROWN CLOUD" STUDY AND COMPUTER MODELING WILL BE USED TO MAKE VISIBILITY PROJECTIONS.

FROM THESE AND OTHER CURRENT AND FUTURE DIESEL EMISSIONS STUDIES WE HOPE TO ADD TO OUR KNOWLEDGE OF DIESEL EMISSIONS. BASED ON OUR CURRENT KNOWLEDGE, WE FEEL IT IS PRUDENT TO PROCEED CAUTIOUSLY WITH THE "DIESEL ISSUE" TO MINIMIZE THE IMPACT OF DIESELS TO INSURE BOTH VISIBILITY AND PUBLIC HEALTH TO THE CITIZENS OF COLORADO.

DIESEL EXHAUST EXPOSURE HEALTH EFFECTS

THIS ANALYSIS WAS DRAWN FROM MATERIAL PRESENTED AT THE 1981 EPA DIESEL EMISSIONS SYMPOSIUM, RESEARCH TRIANGLE PARK, NORTH CAROLINA, AND THE NATIONAL RESEARCH COUNCIL'S REPORT ON HEALTH EFFECTS OF EXPOSURE TO DIESEL EXHAUST, NRC, 1981.

THE PRESENT DATA BASE ON HEALTH EFFECTS OF DIESEL EXHAUST CONSISTS OF EXPERIMENTS WITH BACTERIA, MAMMALIAN CELLS, MAMMALIAN TISSUE AND LIVE ANIMAL EXPOSURE TO DIESEL EXHAUST (BOTH DILUTED AND UNDILUTED), WHOLE DIESEL PARTICULATES, PARTICULATE EXTRACTS AND GAS-PHASE COMPONENTS OF DIESEL EXHAUST, AND HUMAN EPIDEMIOLOGY STUDIES. THESE STUDIES HAVE FOCUSED ON THE MUTAGENIC, CARCINOGENIC AND PULMONARY EFFECTS OF DIESEL EXHAUST.

MUTAGENISIS

IN VITRO STUDIES OF DIESEL PARTICULATES WITH AMES BIASSAY TESTS HAVE INDICATED GENOTOXIC ACTIVITY AND, THEREFORE, POSSIBLE CARCINOGENIC ACTIVITY. THESE MUTAGENIC COMPOUNDS ARE FOUND IN THE SOLUBLE ORGANIC FRACTION OF THE DIESEL PARTICULATE. IN VITRO STUDIES HAVE ALSO INDICATED SOME DIESEL ENGINES MAY CONTAIN SUFFICIENT LEVELS OF BIOLOGICAL CARCINOGENS TO PRODUCE CELL TRANSFORMATION. FUEL VARIABLES AND ENGINE OPERATING CHARACTERISTICS SEEM TO BE A FACTOR IN THE BIOLOGICAL ACTIVITY OF DIESEL EXHAUST PARTICULATE. IT IS UNCERTAIN WHETHER IN VIVO STUDIES WILL GIVE THE SAME RESULTS.

CARCINOGENISIS

EXTRACTS FROM DIESEL EXHAUST PARTICULATES CONTAIN KNOWN CARCINOGENIC MATERIAL (NITROPYRENE, BENZO(A)PYRENE). SKIN TUMOR INITIATION STUDIES INDICATE THE ACTIVITIES OF ROOFING TAR, COKE-OVEN EFFLUENT, EXHAUST COMPONENTS FROM GASOLINE AND DIESEL ENGINES ARE APPROXIMATELY THE SAME. HOWEVER, CHANCE OF HUMAN EXPOSURE TO THESE VARIOUS POLLUTANTS WAS NOT CONSIDERED IN THESE STUDIES. STUDIES BY GENERAL MOTORS CLAIM EMISSIONS FROM DIESEL ENGINES ARE NO MORE POTENTIALLY DANGEROUS THAN EMISSIONS FROM OTHER COMBUSTION SOURCES.

DIESEL ENGINE PARAMETERS, OPERATING CHARACTERISTIC AND FUEL TYPE GREATLY AFFECT CARCINOGENIC ACTIVITY. AT THIS TIME, IT APPEARS THAT CARCINOGENIC ACTIVITY OF DIESEL PARTICULATES IS LOW. LONG-TERM STUDIES WOULD BE NECESSARY BEFORE THIS COULD BE VIEWED AS CONCLUSIVE.

PULMONARY

DIESEL EXHAUST PARTICULATES ARE IN THE RESPIRATORY SIZE RANGE TO BE DEPOSITED DEEP WITHIN THE LUNG. THE PARTICULATES EVENTUALLY BECOME SEQUESTERED IN THE ALVEOLAR MACROPHAGES. THESE MATERIALS ARE THEN SLOWLY REMOVED FROM THE LUNG OR ABSORBED BY THE BODY. INHALED MATERIAL MAY INDUCE BIOCHEMICAL CHANGES IN ORGANS DISTANT FROM THE RESPIRATORY TRACT (I.E., KIDNEY, LIVER). PULMONARY DEFENSE MECHANISM MAY BE DIMINISHED BY DIESEL EXHAUST. IT IS NOT KNOWN AT THIS TIME WHETHER THIS IS DUE TO THE GASEOUS OR PARTICULATE PHASE OF DIESEL EXHAUST. IT IS ALSO NOT KNOWN WHETHER HISTOPATHOLOGICAL CHANGES IN THE LUNG DUE TO DIESEL EXPOSURE ARE REVERSIBLE AFTER EXPOSURE HAS CEASED.

HIGH EXPOSURE LEVELS OF DIESEL EXHAUST CAN PRODUCE PULMONARY TOXICITY. THE EFFECTS OF LOW LEVEL, LONG-TERM EXPOSURE IS STILL UNCERTAIN.

THERE IS A POSSIBILITY OF SYNERGISTIC INTERACTION BETWEEN INHALED DIESEL PARTICULATES AND OTHER INHALED SUBSTANCES (I.E., CIGARETTE SMOKE, OTHER AMBIENT POLLUTANTS). LITTLE IS KNOWN ON THE CARDIOPULMONARY EFFECTS OF WHOLE DIESEL EXHAUST, EVEN THOUGH SOME SUBSTANCES IN DIESEL EXHAUST ARE KNOWN TO HAVE ADVERSE EFFECTS.

EPIDEMIOLOGY

A LIMITED NUMBER OF EPIDEMIOLOGICAL STUDIES OF OCCUPATIONAL EXPOSURE TO DIESEL EXHAUST HAVE BEEN CONDUCTED. ALSO, A LIMITED NUMBER OF STUDIES ARE CURRENTLY IN PROGRESS. TWO SIGNIFICANT STUDIES INVOLVED RAILROAD WORKERS AND BUS GARAGE WORKERS. NO EXCESS RISK OF CANCER WAS SIGHTED IN EITHER OF THESE STUDIES;

HOWEVER, SEVERAL FLAWS HAVE BEEN IDENTIFIED IN THESE STUDIES, THEREFORE, THE EVIDENCE SHOULD NOT BE VIEWED AS CONCLUSIVE.

CONCLUSIONS*

LIGHT DUTY MOTOR VEHICLES EQUIPPED WITH DIESEL ENGINES GIVE GOOD MILEAGE AND HAVE RELATIVELY LOW EMISSIONS OF CARBON MONOXIDE (CO) AND REACTIVE HYDROCARBONS (HC). UNFORTUNATELY, COMPARED WITH GASOLINE FUELED LIGHT DUTY MOTOR VEHICLES OF COMPARABLE SIZE EQUIPPED WITH A THREE-WAY CATALYST, THEY EMIT SIGNIFICANTLY MORE OXIDES OF NITROGEN (NO_x) AND 30 TO 100 TIMES MORE PARTICLES. THUS, PROJECTIONS OF GREATLY INCREASED SALES OF LIGHT DUTY DIESELS HAVE SERIOUS IMPLICATIONS FOR RESIDENTS OF COLORADO'S ALREADY POLLUTED FRONT RANGE. THESE INCLUDE NOT ONLY VISIBILITY DEGRADATION BY CARBONACEOUS AND SULFATE PARTICLES, BUT ALSO INCREASES IN AMBIENT LEVELS OF CHEMICAL MUTAGENS AND CARCINOGENS ASSOCIATED WITH PARTICULATE ORGANIC MATTER (POM).

DIESEL PARTICULATE ORGANIC MATTER FALLS IN THE RESPIRABLE SIZE RANGE, AND ORGANIC EXTRACTS CONTAIN NOT ONLY SUCH CLASSICAL CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS (PAH) AS BENZO(A) PYRENE (BaP), BUT ALSO CHEMICAL SPECIES WHICH, IN CONTRAST TO BENZO(A)PYRENE [WHICH REQUIRES METABOLIC ACTIVATION (S9)] ARE POWERFUL, DIRECT FRAMESHIFT MUTAGENS. MAJOR CONTRIBUTORS TO THIS DIRECT MUTAGENIC ACTIVITY IN BACTERIA ARE CERTAIN NITROARENES SUCH AS 1-NITROPHYRENE (1-NO). RECENTLY, THIS COMPOUND HAS ALSO BEEN REPORTED TO BE A POTENT CARCINOGEN WHEN ADMINISTERED TO RATS

[OHGAKI ET AL., CANCER LETT., 15, 1 (1981)]. OTHER POWERFUL BACTERIAL MUTAGENS (AND POSSIBLE CARCINOGENS) ARE ALSO PRESENT IN DIESEL PARTICULATE ORGANIC MATTER WHICH DISPLAYS GENOTOXIC ACTIVITY.

IT IS IMPORTANT TO NOTE THAT PARTICULATE ORGANIC MATTER FROM EXHAUST EMISSIONS OF GASOLINE LIGHT DUTY MOTOR VEHICLES, AND PROBABLY AMBIENT AIR, ALSO CONTAINS SIMILAR DIRECT AND PROMUTAGENS. HOWEVER, A MAJOR CONCERN OVER A LARGE NUMBER OF DIESEL-EQUIPPED LIGHT DUTY MOTOR VEHICLES IS THAT THEY EMIT FAR MORE OF THESE SPECIES PER MILE (PERHAPS 10 TIMES) THAN DO PRESENT CATALYST EQUIPPED GASOLINE POWERED LIGHT DUTY MOTOR VEHICLES.

IN VIEW OF THIS, IT IS ESSENTIAL (1) THAT DIESEL PARTICULATE ORGANIC MATTER BE CONTROLLED AS STRINGENTLY AS ALLOWED BY PRESENT TECHNOLOGY; (2) THAT STRICTER FEDERAL EMISSION STANDARDS BE SUPPORTED FOR 1985 TO ENCOURAGE THE DEVELOPMENT AND USE OF NEW, ADVANCED TECHNOLOGICAL CONTROLS FOR BOTH THE ENGINE AND EXHAUST SYSTEMS; AND (3) THAT FEASIBLE DIESEL PARTICULATE CONTROL MEASURES BE SUPPORTED AT THE STATE LEVEL.

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*PREPARED FROM "MUTAGENS, CARCINOGENS AND OTHER TOXIC CHEMICALS IN DIESEL EXHAUST", BY JAMES N. PITTS, JR., PH.D., UNIVERSITY OF CALIFORNIA

MOTOR VEHICLE EMISSIONS CONTROL CONFERENCE

MAY 5-7, 1982 SCOTTSDALE, ARIZONA

SPONSORED BY: STATE AND TERRITORIAL AIR POLLUTION
PROGRAM ADMINISTRATORS

SESSION IV - CURRENT AND NEW CONTROL TECHNOLOGY - OTHER SOURCES

MODERATOR: JOHN PATTISON - UNIVERSITY OF CINCINNATI

HEAVY-DUTY VEHICLE EMISSIONS CONTROL

JOHN MCNALLY - CATERPILLAR TRACTOR CO.

Emission Control For Heavy-Duty Diesel Engines

By J. J. McNally

I. On-Highway Truck Engines
  A. Truck Classes
  B. Emission Regulations
  C. Emission Control Techniques
  D. Emission Control "Tradeoffs"
    1. Fuel Consumption
    2. Performance
    3. Other Emissions
  E. Exhaust Aftertreatment
  F. Summary

II. Off-Highway Equipment Engines
  A. Equipment Categories
  B. Variety of Equipment and Manufacturers
  C. Impact on Air Quality
    1. CARB Study
    2. Industry Study
    3. Preliminary Results
  D. Summary

INTRODUCTION

GOOD AFTERNOON.

SLIDE 1. BLANK

SLIDE 2. MY SUBJECT THIS AFTERNOON IS EMISSIONS CONTROL OF HEAVY-DUTY DIESEL ENGINES. EMISSIONS BY OUR DEFINITION ARE THE PRODUCTS OF COMBUSTION THAT ARE EXHAUSTED FROM THE ENGINE INTO THE ATMOSPHERE.

SLIDE 3. DIESEL ENGINES ARE USED IN BOTH ON-HIGHWAY AND OFF-HIGHWAY APPLICATIONS. SINCE THESE TWO TYPES OF APPLICATIONS ARE SO DISTINCTLY DIFFERENT, I WILL DISCUSS EACH SEPARATELY.

SLIDE 4. FIRST, I WOULD LIKE TO COMMENT ON THE ON-HIGHWAY TRUCKING INDUSTRY. THIS IS A MULTI-BILLION DOLLAR PER YEAR BUSINESS THAT MOVES A LARGE PORTION OF THE GOODS AND MATERIALS THAT WE, AS CONSUMERS, ARE SO DEPENDENT UPON. AS YOU KNOW, TRUCKS CAN RANGE FROM THE PERSONAL USE PICKUP TRUCK TO THE LARGE 18 WHEELERS THAT WE SEE IN LARGE NUMBERS ON THE INTERSTATE HIGHWAY SYSTEM.

SLIDE 5. WHEN WE SPEAK OF HEAVY-DUTY ON-HIGHWAY DIESEL ENGINES, WE ARE LIMITING OUR DISCUSSION TO THE SIZES AND TYPES OF TRUCKS AT THE LARGER END OF THE SCALE -- THOSE THAT REQUIRE HIGHER HORSEPOWER AND LONGER LIFE THAN PICKUP AND VAN TYPE TRUCKS.

SLIDE 6. CATERPILLAR TRACTOR CO. DOES NOT BUILD ON-HIGHWAY TRUCKS. WE SELL A FULL LINE OF DIESEL ENGINES TO ON-HIGHWAY TRUCK MANUFACTURERS. WE ARE ONE OF SEVERAL ENGINE MANUFACTURERS THAT SUPPLY ENGINES TO APPROXIMATELY 15 DIFFERENT TRUCK MANUFACTURERS IN THE UNITED STATES. IN MANY CASES, A BUYER CAN CHOOSE BETWEEN TWO OR THREE DIFFERENT ENGINE MAKES FOR A GIVEN TRUCK. WITH THESE ENGINE OPTIONS AVAILABLE, THE TRUCK ENGINE BUSINESS IS HIGHLY COMPETITIVE AND THE ENGINES ARE CAREFULLY ENGINEERED AND PRECISION MANUFACTURED. THIS COMPETITION

SLIDE 7. HAS PRODUCED ENGINES THAT HAVE THE CAPABILITY OF OPERATING IN THE 300 TO 400 THOUSAND MILE RANGE BEFORE REQUIRING AN OVERHAUL. IT IS NOT UNCOMMON TO HEAR OF ENGINES OPERATING MORE THAN A MILLION MILES WITH, OF COURSE, GOOD MAINTENANCE AND TIMELY REPLACEMENT OF CERTAIN PARTS.

SLIDE 8. WHEN WE SPEAK OF HEAVY-DUTY TRUCKS. WE NEED TO PUT INTO PERSPECTIVE WHAT IS MEANT BY A TRULY HEAVY-DUTY TRUCK. THE TRUCK INDUSTRY USES GROSS VEHICLE WEIGHT RATING OR GVWR AS A BASIS FOR REPORTING PRODUCTION AND SALES DATA. INDUSTRY TRUCK CLASSES RANGE FROM CLASS 1 THROUGH CLASS 8 WITH AN APPROPRIATE GVWR WEIGHT AS SHOWN. EPA HAS CHOSEN TO DEFINE A HEAVY-DUTY TRUCK AS A VEHICLE EXCEEDING 8.500 POUNDS GVWR. THOSE VEHICLES BETWEEN 6.000 AND 8.500 POUNDS GVWR ARE CONSIDERED LIGHT-DUTY TRUCKS AND COME UNDER SEPARATE EPA REGULATIONS.

THE EPA DEFINITION OF A HEAVY-DUTY TRUCK COVERS A BROAD RANGE AND WE. AS A MANUFACTURER. WOULD CONSIDER THE UPPER PART OF CLASS II THROUGH V AS MEDIUM-DUTY TRUCKS. THE ENGINES FOR THESE TRUCKS ARE DESIGNED FOR PICKUP AND DELIVERY TYPE APPLICATIONS AND ARE NOT DESIGNED TO HAVE THE DURABILITY OF AN ENGINE USED FOR A LARGE CROSS COUNTRY TYPE TRUCK. EPA REGULATIONS PRESENTLY REQUIRE THAT ENGINES IN ALL CLASSES MEET IDENTICAL DURABILITY TEST REQUIREMENTS.

SLIDE 9. I SHOULD MENTION BRIEFLY SOME OF THE PROVISIONS OF HEAVY-DUTY TRUCK ENGINE EMISSIONS REGULATIONS. PERHAPS YOU HAVE SEEN NEWS ARTICLES COVERING THE CLEAN AIR ACT AND ENVIRONMENTAL ACTIVITY GENERALLY. THAT STATE OR IMPLY THAT THERE ARE NO CONTROLS ON HEAVY-DUTY ENGINES.

WE HAVE HAD CONTROLS FOR OVER TEN YEARS AND. IN FACT. EPA REGULATED DIESEL EXHAUST SMOKE STARTING IN 1970. THE CALIFORNIA AIR RESOURCES BOARD STARTED CONTROLLING GASEOUS EMISSIONS IN 1973. AS THIS SLIDE SHOWS. THERE HAVE BEEN CHANGES BY EITHER EPA OR CARB ALMOST EVERY YEAR WHICH INCREASED THE STRINGENCY OF THE REGULATIONS.

SLIDE 10. WHEN WE SPEAK OF CONTROLLING EMISSIONS FROM HEAVY-DUTY ENGINES. WE RECOGNIZE THAT OUR ACTIONS ARE CONTROLLED AND INFLUENCED BY LAWS. FIRST. THERE ARE STATUTORY LAWS WHICH SERVE AS THE AUTHORITY FOR REGULATIONS TO WHICH A PRODUCT MUST COMPLY BEFORE IT CAN BE LEGALLY INTRODUCED INTO THE MARKETPLACE. NEXT. THERE ARE THE LAWS OF
SLIDE 11. ECONOMICS. EVEN THOUGH A PRODUCT MAY COMPLY WITH THE STATUTORY LAWS. IT MUST BE MANUFACTURED AND SOLD AT A PRICE THAT IS COMPETITIVE. AND A PROFIT REALIZED ON THE INVESTMENT INVOLVED. AND IN ADDITION. THE PRODUCT MUST HAVE ACCEPTABLE PERFORMANCE AND REPRESENT VALUE TO A BUYER IN ORDER FOR HIM TO PRODUCE A PROFIT. THESE PRODUCTS ARE CLEARLY CAPITAL GOODS.

SLIDE 12. FROM AN ENGINEER'S STANDPOINT. THE MOST RIGID LAWS PERHAPS ARE THE LAWS OF THERMODYNAMICS. THE COMBUSTION PROCESS IN AN ENGINE CANNOT BE CHANGED SIGNIFICANTLY WITHOUT INCURRING SOME PENALTY IN PERFORMANCE OR ECONOMY. I WILL TALK IN MORE DETAL ABOUT THIS PROBLEM LATER.

SLIDE 13. SINCE I WILL BE DISCUSSING ENGINE MODIFICATIONS FOR EMISSION CONTROL, I WANT TO ORIENT YOU TO AREAS OF THE ENGINE I WILL BE DISCUSSING. THE MODIFICATIONS GENERALLY TAKE PLACE IN THE COMBUSTION, VALVE TRAIN, AIR INLET, TURBOCHARGER, FUEL SYSTEMS AREAS OF THE ENGINE AS INDICATED BY THIS CROSS SECTION OF A TYPICAL ENGINE. THESE AREAS ARE THE "HEART" OF AN ENGINE AND CHANGING ANY ONE OF THESE HIGHLY PERCISION-BUILT PARTS CAN HAVE AN IMPACT ON OTHER PARTS OR SYSTEMS. MOST OF THESE PARTS HAVE BENEFITTED FROM LITERALLY YEARS OF DEVELOPMENT AND CHANGES REQUIRE CONSIDERABLE PROVE-OUT BEFORE BEING ACCEPTED FOR PRODUCTION.

SLIDE 14. ENGINE MODIFICATIONS FOR EMISSION CONTROL PURPOSES CAN BE EXTENSIVE AND TO GIVE SOME PERCEPTION OF THE NATURE AND EXTENT OF THESE MODIFICATIONS, WE HAVE PREPARED A SUMMARY LIST. THIS IS BY NO MEANS ALL INCLUSIVE BUT IT DOES SHOW WHAT WE CONSIDER THE SIGNIFICANT COMPONENTS AND ENGINE MODIFICATIONS THAT AFFECT EMISSIONS. IT WOULD SEEM ON THE SURFACE THAT HAVING ACCESS TO THIS MANY EMISSION CONTROL TECHNIQUES IT WOULD BE A SIMPLE TASK TO REDUCE EMISSIONS. UNFORTUNATELY, THERE IS PROBABLY NO SINGLE ITEM ON THIS LIST THAT WILL REDUCE ALL TYPES OF EMISSION SIMULTANEOUSLY. A CHANGE THAT WILL REDUCE HYDROCARBONS (OR HC) MAY CAUSE OXIDES OF

NITROGEN (OR NO_X) TO INCREASE. A CHANGE TO REDUCE NO_X MAY CAUSE PARTICULATES TO INCREASE. IT IS, IN OTHER WORDS, A TRADE-OFF PROCESS, A CAREFUL BALANCING OF THE SEVERAL VARIABLES TO PRODUCE THE BEST COMPROMISE THAT WILL PERMIT THE ENGINE TO MEET ALL THE DEMANDS PLACED ON IT. IT IS IMPORTANT TO REMEMBER THAT AN ENGINE MUST DO MUCH MORE THAN MEET EMISSIONS
SLIDE 15. REQUIREMENTS TO BE A VIABLE PRODUCT. TO BE MORE SPECIFIC, LET'S LOOK AT THE TRENDS THAT RESULT FROM CHANGING THE FUEL INJECTION TIMING ON A DIESEL ENGINE.

INJECTION TIMING IS AN EXPRESSION USED TO INDICATE THE POSITION OF THE CRANKSHAFT AND PISTON WHEN FUEL IS INJECTED INTO THE CYLINDER. THIS INJECTION OF FUEL STARTS THE COMBUSTION PROCESS AND THE POWER PRODUCED AND EFFICIENCY OF THE ENGINE IS AFFECTED BY INJECTION TIMING.

RETARDING THE TIMING OR STARTING FUEL INJECTION LATER ON A DIESEL ENGINE TO REDUCE EMISSIONS HAS BEEN SUGGESTED BY MANY AS A WAY TO REDUCE NO_X. AS SHOWN, RETARDED TIMING TRULY DOES REDUCE NO_X SIGNIFICANTLY BUT LOOK WHAT HAPPENS TO SMOKE AND FUEL CONSUMPTION. THE RETARDED TIMING IS CAUSING THE COMBUSTION PROCESS TO OCCUR LATE WHICH RESULTS IN INCOMPLETE BURNING OF THE FUEL AND LOWER COMBUSTION TEMPERATURES. THIS PRODUCES

LOWER NO_x BUT HIGHER SMOKE AND HIGHER FUEL CONSUMPTION. FOR OPTIMUM ENGINE EFFICIENCY, WE WOULD EXPECT TO TIME THIS PARTICULAR ENGINE AT 26° BEFORE TOP CENTER. BUT FOR LOWER NO_x, WE HAVE TO CONSIDER WHAT IS ACCEPTABLE IN TERMS OF INCREASED SMOKE AND FUEL CONSUMPTION--PROBABLY NONE AS SHOWN. SO, THE NEXT STEP WOULD BE TO DETERMINE WHAT OTHER CHANGES COULD BE MADE TO RETAIN THE LOW NO_x YET NOT INCREASE SMOKE AND FUEL CONSUMPTION. THIS STARTS A JUGGLING ACT OF TRYING TO BALANCE ONE CHANGE AGAINST ANOTHER UNTIL AN OPTIMUM COMBINATION CAN BE IDENTIFIED.

SLIDE 16. TO SEE WHAT THIS JUGGLING ACT LOOKS LIKE, LET'S CONSIDER WHAT HAPPENS WHEN YOU ATTEMPT TO UTILIZE A PARTICULAR TECHNOLOGY TO CONTROL ONE EMISSION AND THE RESULT IS AN INCREASE IN ANOTHER EMISSION OR A PENALTY IN PERFORMANCE. THIS CHART SHOWS A NUMBER OF ENGINE MODIFICATIONS AND THE EXPECTED RESULT ON HYDROCARBONS, NITRIC OXIDES, SMOKE AND FUEL CONSUMPTION. ITS A KIND OF "WHAT IF" PROCESS. THE ARROWS POINTING UP INDICATE AN INCREASE WHILE THE ARROWS POINTING DOWN INDICATE A DECREASE. RATHER THAN TAKING THE TIME TO DISCUSS EACH

SLIDE 17. MODIFICATION INDIVIDUALLY, LET'S TAKE EGR FOR EXAMPLE. EGR OR EXHAUST GAS RECIRCULATION IS WHERE SOME OF THE EXHAUST GAS IS DIVERTED FROM THE EXHAUST SYSTEM AND MIXED WITH THE FRESH AIR ENTERING THE ENGINE.

SLIDE 18. RECIRCULATED. IN OTHER WORDS. THE EXHAUST GAS RAISES THE TEMPERATURE OF THE AIR ENTERING THE ENGINE AND REDUCES THE OXYGEN AVAILABLE FOR COMBUSTION WHICH IN TURN RESULTS IN REDUCED NO_x. LOOK AT THE FOURTH LINE. AS SHOWN WITH THE REDUCED NO_x. HYDROCARBONS ARE ALSO LOWER BUT SMOKE AND FUEL CONSUMPTION ARE HIGHER. EGR IS VERY EFFECTIVE IN REDUCING NO_x BUT IT WILL PROBABLY HAVE LITTLE OR NO ACCEPTANCE AS FURTHER EMPHASIS IS PLACED ON PARTICULATE CONTROL.

SLIDE 19. TO THE OWNER OR OPERATOR OF A TRUCK, AN IMPORTANT MEASURE OF AN ENGINE IS ITS FUEL CONSUMPTION. THIS IS A DIRECT OUT OF POCKET EXPENSE THAT HE HAS TO CONTEND WITH EVERY TIME HE OPERATES THE VEHICLE AND CAN MAKE THE DIFFERENCE BETWEEN PROFIT AND LOSS. WE ARE ALL MUCH MORE ENERGY CONSCIOUS TODAY THAN WE WERE SOME YEARS AGO SO IT IS EXTREMELY IMPORTANT THAT WE EXAMINE AND UNDERSTAND THE TRADEOFFS BETWEEN LOW EMISSIONS AND FUEL CONSUMPTION. THIS GRAPH SHOWS THE RANGE OF FUEL CONSUMPTION CHANGE AS NO_x IS REDUCED FOR OUR ENGINE MODEL LINE. THE GREEN CURVE WITH THE LEAST FUEL CONSUMPTION INCREASE IS FOR A LARGE HEAVY-DUTY TRUCK ENGINE THAT IS USED PRIMARILY ON CROSS COUNTRY OR LONG HAUL TYPE TRUCKS. THE RED CURVE IS MORE INDICATIVE OF A PICK UP AND DELIVERY TYPE TRUCK - THE KIND MORE OFTEN USED IN URBAN AREAS.

SLIDE 20. IT IS NO SECRET THAT DIESEL ENGINES, PARTICULARLY THOSE THAT IMPROPERLY MAINTAINED, CAN AND OFTEN DO PRODUCE OBJECTIONABLE SMOKE. THERE IS A STRONG CORRELATION BETWEEN THIS TYPE OF SMOKE EMISSION AND PARTICULATES BECAUSE UNDER CERTAIN OPERATING CONDITIONS THERE ARE UNBURNED FUEL HYDROCARBONS IN ADDITION TO THE SOOT IN THE EXHAUST. CONCERN OVER VISIBILITY LOSS AND SUSPECTED, BUT NOT YET PROVEN, HEALTH EFFECTS HAS RESULTED IN PROPOSED REGULATORY CONTROL OF

SLIDE 21. PARTICULATES. HERE AGAIN, WE MUST ENTER INTO THE TRADEOFF PROCESS BECAUSE IN ADDITION TO LOWERING PARTICULATES, WE ARE ALSO TRYING TO LOWER NO_X. AGAIN A HEAVY-DUTY AND MEDIUM TRUCK ARE DEPICTED ON THIS GRAPH.

SLIDE 22. ANOTHER EMISSION CONTROL TECHNIQUE WHICH WE HAVE EVALUATED IS AFTERTREATMENT OF THE EXHAUST. MOST CATALYSTS ARE INEFFECTIVE WITH A DIESEL ENGINE BECAUSE THERE IS ALWAYS EXCESS OXYGEN IN THE EXHAUST OF ANY DIESEL ENGINE WHICH PREVENTS THE CATALYTIC ACTION FROM TAKING PLACE. IN THIS CASE AMMONIA AND SELECTIVE REDUCTION CATALYSTS WERE USED TO REDUCE NITRIC OXIDES BY MORE THAN 50%. THIS SYSTEM REQUIRED AN AMMONIA SUPPLY CARRIED ON THE TRUCK AND A CONTROL SYSTEM TO METER AMMONIA INTO THE EXHAUST IN PROPORTION TO THE ENGINE LOAD AND SPEED. THE MAJOR OBJECTION TO THIS TYPE OF

EMISSIONS CONTROL FROM A REGULATORY STANDPOINT WAS THE USER PARTICIPATION REQUIRED TO REPLENISH THE AMMONIA. ALSO, AMMONIA COSTS COULD AMOUNT TO 2-3% OF THE FUEL COSTS, BUT THIS IS PROBABLY LESS SIGNIFICANT THAN THE INCONVENIENCE OF REPLENISHING THE AMMONIA TO SAY NOTHING OF THE NEED TO ASSURE ITS CONSTANT USE. ALTHOUGH THE FEASIBILITY TESTS AND LIMITED FIELD TESTS WERE SUCCESSFUL, THIS TYPE OF UNIT CANNOT BE CONSIDERED COMMERCIALLY FEASIBLE FOR VEHICLE APPLICATIONS OR ACCEPTABLE TO THE REGULATORY AGENCIES WE'VE SHOWN IT TO.

SLIDE 23. ANOTHER TYPE OF AFTERTREATMENT BEING INVESTIGATED IS FOR PARTICULATE CONTROL. THIS TYPE OF EXHAUST TREATMENT, IN EFFECT, FILTERS OUT THE PARTICULATES MUCH THE SAME AS AN AIR CLEANER FILTERS OUT THE DIRT FROM THE AIR ENTERING THE ENGINE.

WE BELIEVE THERE ARE THREE MAJOR COMPONENTS INVOLVED IN PARTICULATE CONTROL WHICH ARE - THE FILTER MEDIA, THE CONTAINER, AND THE CONTROL SYSTEM. THE FILTER, WHICH CAN BE A CERAMIC HONEYCOMB OR A STEEL WOOL TYPE LIKE MATERIAL, MAY BE TREATED WITH A CATALYST. THESE TYPES OF MATERIALS HAVE BEEN DEMONSTRATED SUCCESSFULLY UNDER CAREFULLY CONTROLLED CONDITIONS BY A NUMBER OF SUPPLIERS.

THE SECOND REQUIREMENT IS FOR A CONTAINER TO ENCLOSE THIS FILTER MEDIA AND PERMIT IT TO BE INSTALLED IN THE EXHAUST SYSTEM. OBVIOUSLY, THIS CONTAINER MUST BE SUFFICIENTLY DURABLE TO PROTECT THE FILTER MEDIA FROM THE VIBRATION AND SHOCK LOADING THAT IS TYPICAL OF TRUCK OPERATION. ALL EXHAUST SYSTEM COMPONENTS OPERATE IN A HOSTILE ENVIRONMENT AND ARE SUBJECT TO FAIRLY FREQUENT FAILURE.

THE CONTROL IS THE THIRD AND PROBABLY THE MOST IMPORTANT ELEMENT OF THE SYSTEM. AS A TRAP COLLECTS PARTICULATES, IT GRADUALLY BECOMES PLUGGED UNTIL ENGINE EXHAUST BACK PRESSURE BECOMES EXCESSIVE. AT THIS POINT, THE TRAP MUST BE REGENERATED. BY THIS, I MEAN THE MATERIAL COLLECTED MUST BE BURNT AWAY SO THAT THE FILTER CAN BE RESTORED TO ITS ORIGINAL OPERATING CONDITION. A REGENERATION CYCLE REQUIRES FAIRLY HIGH TEMPERATURES TO START THE CYCLE AND THEN ONCE STARTED, IT IS IMPORTANT TO PROVIDE A CONSTANT SUPPLY OF OXYGEN SO THAT THE BURNING CYCLE WILL CONTINUE AT THE DESIRED RATE THROUGH THE TRAP. THIS BURNING PROCESS MUST BE CLOSELY CONTROLLED IN ORDER TO ACHIEVE A COMPLETE REGENERATION CYCLE AND AVOID UNCONTROLLED BURNING WHERE TEMPERATURES COULD BECOME EXCESSIVE AND DESTROY THE FILTER MEDIA, OR WORSE, SET FIRE TO THE VEHICLE AND ITS SURROUNDINGS.

MANY APPROACHES ARE BEING CONSIDERED TO CONTROL THE REGENERATION CYCLE AND AT PRESENT, THE CONTROL SYSTEM IS STILL IN THE INVENTION STAGE. THERE IS LITTLE DOUBT THAT AN ACCEPTABLE SYSTEM WILL BE DEVELOPED BUT A TIMETABLE FOR PRODUCTION AVAILABILITY CANNOT BE IDENTIFIED TODAY.

SLIDE 24. IF ONE WORD WERE TO BE USED TO CHARACTERIZE HEAVY-DUTY DIESEL TRUCK ENGINE EMISSIONS CONTROL, IT IS WOULD BE "TRADEOFFS". NOT ONLY ARE THERE TRADEOFFS BETWEEN FUEL CONSUMPTION, COST AND PERFORMANCE, BUT THERE ARE THE OTHER TRADEOFFS AS BETWEEN THE EXHAUST EMISSIONS THEMSELVES. ANY PROGRAM FOR THE CONTROL OF EMISSIONS MUST TAKE INTO CONSIDERATION ALL COMPONENTS OF THE EXHAUST GAS . THE ENGINE ITSELF IS ALSO A COMPLEX PIECE OF EQUIPMENT IN THAT MOST MODIFICATIONS IMPACT UPON OTHER OPERATING CHARACTERISTICS ALL OF WHICH REQUIRES CAREFUL EVALUATION SO AS NOT TO AFFECT THE FUNDAMENTAL PURPOSE OF THE ENGINE - TO PRODUCE POWER TO DO USEFUL WORK.

SLIDE 25. NOW I WOULD LIKE TO TURN TO OFF-HIGHWAY EQUIPMENT AND EMISSIONS. FOR THE PURPOSE OF THIS DISCUSSION,

SLIDE 26. OFF-HIGHWAY EQUIPMENT FALLS INTO THREE CATEGORIES - AGRICULTURAL, CONSTRUCTION, AND INDUSTRIAL.

SLIDE 27. THE AGRICULTURAL, CONSTRUCTION, AND INDUSTRIAL CATAGORIES COVER A LARGE VARIETY OF EQUIPMENT PRODUCED BY A LARGE NUMBER OF MANUFACTURERS, MOST OF WHOM YOU WILL RECOGNIZE AND OTHERS YOU MAY NEVER HAVE ENCOUNTERED.

SLIDE 28. AS SOME OF YOU MAY KNOW, THE IMPACT OF OFF-HIGHWAY EQUIPMENT ON AMBIENT AIR QUALITY HAS BEEN THE SUBJECT OF A STUDY BY THE CALIFORNIA AIR RESOURCES BOARD STAFF. TO HELP ASSEMBLE INFORMATION FOR OFF-HIGHWAY EQUIPMENT AND TO AID IN MAKING SOUND DECISIONS, AN INDUSTRY SPONSORED STUDY WAS UNDERTAKEN. MOST EQUIPMENT AND ENGINE MANUFACTURERS PARTICIPATED IN THIS STUDY BOTH FINANCIALLY AND BY PROVIDING DATA RELATING TO THEIR EQUIPMENT. THIS STUDY IS NEARLY COMPLETE AND WILL BE REVIEWED SHORTLY WITH THE CALIFORNIA AIR RESOURCES BOARD STAFF. AS AN INDICATION OF THE COMPLEXITY OF THIS INDUSTRY, THERE ARE 13 ENGINE MANUFACTURERS AND 39 EQUIPMENT BUILDERS WHO HAVE PARTICIPATED IN THIS STUDY AND PROVIDED DATA ON 561 ENGINE/MACHINE COMBINATIONS.

SLIDE 29. THIS INDUSTRY STUDY WAS LIMITED TO OFF-HIGHWAY EQUIPMENT SOLD IN THE STATE OF CALIFORNIA AND CATEGORIZED AS FARM AND NON-FARM. THE STUDY INDICATED ABOUT 95% OF THIS EQUIPMENT WAS DIESEL POWERED SO ALL OF MY COMMENTS WILL BE CONFINED TO DIESELS.

SLIDE 30. THE INDUSTRY STUDY OBJECTIVES ARE:

1. COLLECT INDUSTRY WIDE DATA ON BOTH EMISSIONS AND EQUIPMENT SALES, SO THAT SALES WEIGHTED EMISSION FACTORS FOR OFF-HIGHWAY EQUIPMENT COULD BE COMPUTED.

2. ASSESS THE AVAILABILITY AND COSTS OF EMISSION CONTROL TECHNOLOGY.

3. EVALUATE THE IMPACT OF OFF-HIGHWAY EQUIPMENT WITH DIFFERENT EMISSION CONTROL REQUIREMENTS ON AIR QUALITY IN SELECTED CALIFORNIA AIR QUALITY MANAGEMENT DISTRICTS.

SLIDE 31. THE STUDY IS PROVIDING SOME INSIGHT INTO THE DEGREE OF DIFFICULTY IN CONTROLLING EMISSIONS FROM OFF-HIGHWAY ENGINES. THE LEAST DIFFICULT ENGINES TO CONTROL EMISSIONS FROM WILL BE THOSE IN WHICH THE SAME BASIC ENGINE MODEL IS USED FOR BOTH ON AND OFF HIGHWAY APPLICATIONS. NEW ENGINES BEING DESIGNED CAN MORE READILY INCORPORATE EMISSION CONTROL TECHNOLOGY DURING THE DESIGN PROCESS RATHER THAN MODIFYING AN EXISTING DESIGN. A THIRD CATEGORY OF DIFFICULTY WILL BE LARGE, HIGH HORSEPOWER ENGINES USED EXCLUSIVELY FOR OFF-HIGHWAY VEHICLES AND WHERE LITTLE OR NO EXPERIENCE IN EMISSION

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CONTROL IS AVAILABLE. A FINAL CATEGORY WILL BE THE ENGINES BUILT BY MANUFACTURERS THAT DO NOT BUILD HIGHWAY TRUCK ENGINES AND, THEREFORE, HAVE NO BACKGROUND OR DEVELOPED NO TECHNOLOGY FOR EMISSIONS CONTROL. THESE MANUFACTURERS WOULD BE AT A DISADVANTAGE NOT ONLY FROM THE STANDPOINT OF TECHNICAL KNOWLEDGE BUT ALSO FROM THE STANDOINT OF FACILITIES, INSTRUMENTATION, AND TECHNICAL PEOPLE.

SLIDE 32. EMISSION CONTROL TECHNOLOGY FOR OFF-HIGHWAY ENGINES AS
THE INDUSTRY STUDY IS INDICATING IS SIMILAR TO THAT OF
ON-HIGHWAY TRUCK ENGINES. SURVEY RESULTS ARE SHOWING
THAT NO_x WILL BE THE MOST DIFFICULT EMISSION TO
CONTROL. THE OFF-HIGHWAY INDUSTRY STUDY IS INDICATING A
KEY DIFFERENCE FROM HIGHWAY ENGINES AND THAT IS LESS
SLIDE 33. FLEXIBILITY OF DESIGN. OFF-HIGHWAY MACHINES ARE
GENERALLY DESIGNED FOR FAIRLY SPECIFIC APPLICATIONS SO
MODIFICATIONS TO MACHINE PERFORMANCE ARE QUITE LIMITED.
SLIDE 34. THESE MACHINES ALSO ARE OF INTEGRATED DESIGN IN THAT THE
ENGINE, TRANSMISSION, HYDRAULIC SYSTEMS, COOLING
SYSTEMS, AND OTHER DRIVE TRAIN COMPONENTS ARE ALL
SLIDE 35. MATCHED FOR A SPECIFIC MACHINE AND THE APPLICATION FOR
WHICH THE MACHINE IS INTENDED. THIS DIFFERS
SLIDE 36. SIGNIFICANTLY FROM HIGHWAY TRUCKS WHERE AN ALMOST
INFINITE COMBINATION OF TRANSMISSION, AXLE RATIOS CAN BE
SPECIFIED TO MATCH DIFFERENT ENGINE SPEEDS, TORQUE, AND
SLIDE 37. OTHER PERFORMANCE CHARACTERISTICS. OFF-HIGHWAY MACHINES
REQUIRE THAT THE ENGINE PERFORMANCE CHARACTERISTICS BE
CLOSELY MATCHED TO VEHICLE PERFORMANCE.

SLIDE 38. IN MUCH THE SAME MANNER AS HIGHWAY TRUCK ENGINES, THE INDUSTRY STUDY IS SHOWING THAT REDUCED NO_X LEVELS WILL RESULT IN INCREASED FUEL CONSUMPTION FOR OFF-HIGHWAY MACHINES. THIS PLOT IS A RANGE FOR THREE DIFFERENT NO_X LEVELS AND AN AVERAGE TREND. A 5% INCREASE IN FUEL CONSUMPTION MAY NOT SOUND SIGNIFICANT BUT IT CAN MEAN AS MUCH AS 1500 GALLONS PER YEAR FOR A LARGE EARTHMOVING TYPE MACHINE. AT ONE DOLLAR PLUS PER GALLON FOR DIESEL FUEL, SOME VEHICLES WILL HAVE SIGNIFICANT ADDITIONAL ANNUAL FUEL COSTS.

SLIDE 39. TO SUMMARIZE, WHETHER IT BE FOR ON-HIGHWAY OR OFF-HIGHWAY ENGINES, EMISSIONS CONTROL INVOLVES SIMILAR TRADEOFFS. THESE FACTS MUST BE VERY CAREFULLY CONSIDERED DURING ANY STANDARD SETTING PROCESS.

ON-HIGHWAY AND OFF-HIGHWAY ENGINES DO HAVE SOME DISTINCT DIFFERENCES AS WELL AS MANY SIMILARITIES. THEORETICALLY, THE SAME EMISSION CONTROL TECHNIQUES WOULD APPLY TO EITHER TYPE OF ENGINE, BUT THERE ARE SOME PRACTICAL LIMITATIONS FOR OFF-HIGHWAY EQUIPMENT. OFF-HIGHWAY EQUIPMENT IS PRODUCED AND SOLD IN LOW VOLUME COMPARED TO ON-HIGHWAY VEHICLES. OFF-HIGHWAY MACHINES ARE DESIGNED FOR SPECIFIC APPLICATIONS AND EMPLOY A

TOTALLY INTEGRATED DESIGN SO THERE IS LITTLE FLEXIBILITY FROM A POWERTRAIN DESIGN STANDPOINT. ON-HIGHWAY VEHICLES ARE USED IN A BROAD RANGE OF APPLICATIONS AND PROVIDE CONSIDERABLE LATITUDE IN COMPONENT SELECTION AND ENGINE MATCHING.

SLIDE 40. VIRTUALLY ALL OF THE HEAVY TRANSPORTATION AND CONSTRUCTION PROVIDED IN THIS COUNTRY TODAY IS DEPENDENT UPON THE DIESEL ENGINE. THE MACHINES PERFORMING THIS WORK HAVE EVOLVED OVER A PERIOD OF MANY YEARS AND HAVE REACHED A HIGH STATE OF DEVELOPMENT. THE ENGINES IN THESE TRUCKS AND MACHINES HAVE PROVEN THEMSELVES IN VIRTUALLY EVERY CONCEIVABLE APPLICATION WHERE RELIABLE ENGINE POWER IS REQUIRED. WE KNOW OF NO POWER SOURCE THAT IS LIKELY TO REPLACE THE DIESEL ENGINE IN THE NEAR TERM FUTURE. IN ORDER FOR SOCIETY TO CONTINUE TO ENJOY THE BENEFITS THAT DERIVE FROM THE USE OF HEAVY-DUTY DIESEL ENGINES, AND AT THE SAME TIME MAINTAIN NECESSARY AIR QUALITY, IT WILL BE NECESSARY FOR US ALL TO PARTICIPATE IN THE "TRADEOFF" PROCESS THAT I HAVE JUST OUTLINED.

SLIDE 41. BLANK

I APPRECIATE THIS OPPORTUNITY TO SPEAK TO YOU AND TO SHARE WITH YOU SOME OF THE CONSIDERATIONS INVOLVED WITH CONTROLLING EMISSIONS FROM DIESEL ENGINES WHICH POWER BOTH HIGHWAY TRUCKS AND OFF-HIGHWAY MACHINES. I WOULD BE HAPPY TO ANSWER ANY QUESTIONS THAT YOU MAY HAVE. WITHIN THE LIMITS OF THE TIME AVAILABLE.

THANK YOU.

DOCUMENT 1673Y

2

Emission Control

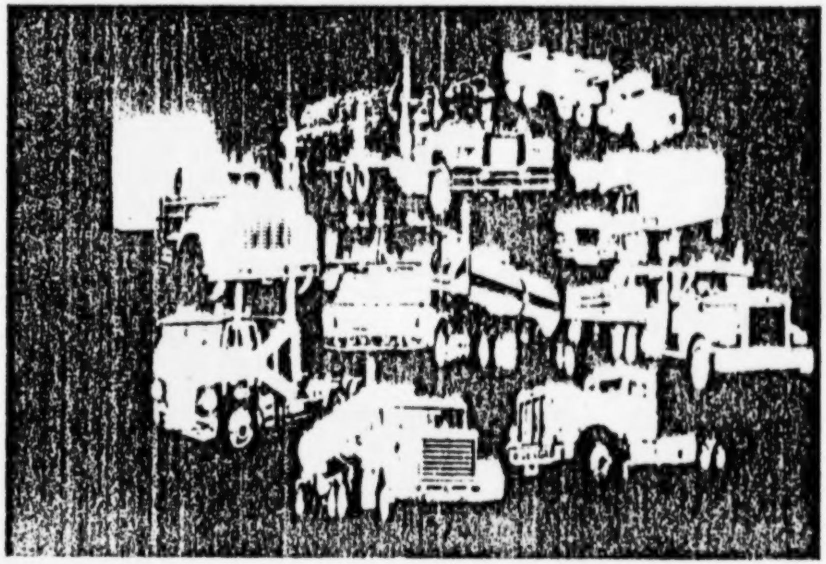
Heavy Duty Diesel Engines

3

Heavy Duty Diesel Engines

- On-Highway Trucks
- Off-Highway Vehicles

4



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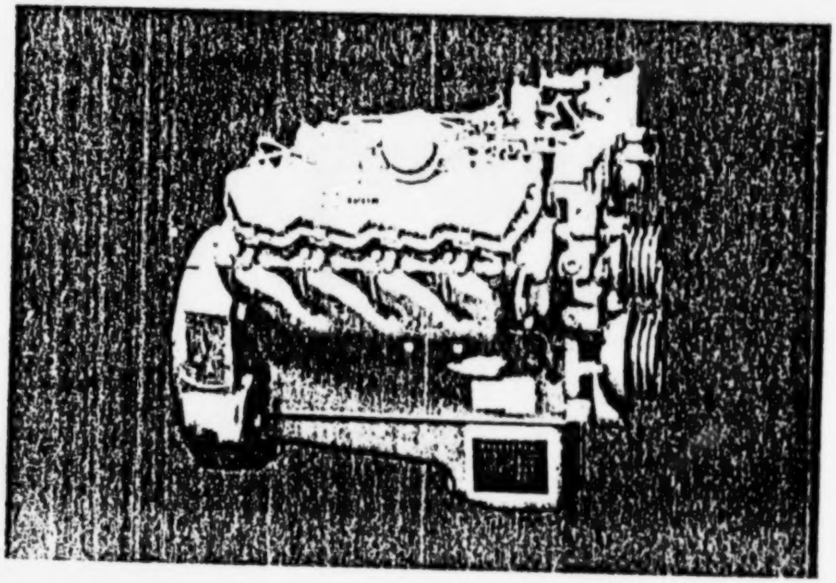

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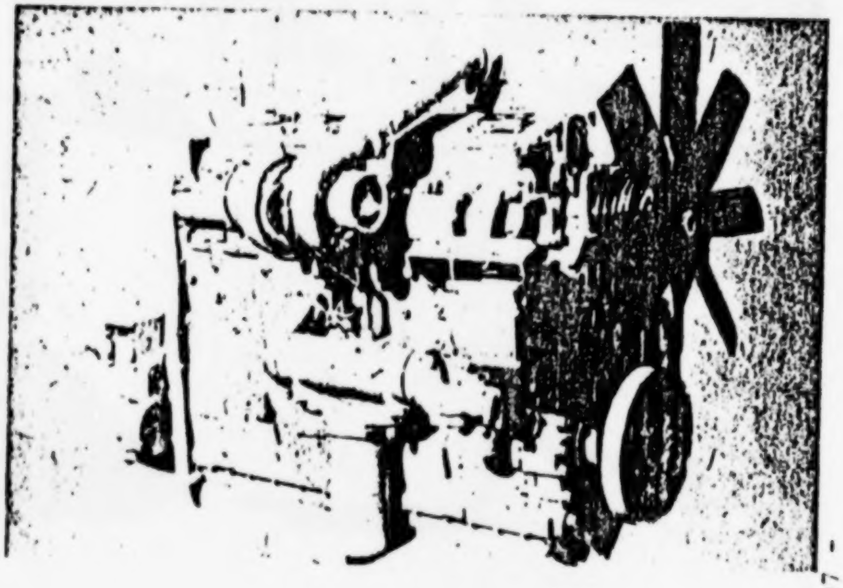


8

Truck Classifications

Industry Class	Weight-Lbs GVWR	EPA Class
I	0-6000	Light Duty Truck
II	6001-8500	↓
VI	19501-26000	
VII	26001-33000	
VIII	33001 & Over	↓

9

Heavy Duty Truck Engine

Emissions Regulations

1970 — EPA	— Exhaust Smoke Standards
1973 — CARB	— Gaseous Emissions Standards
1974 — EPA	— Gaseous Emissions Standards & More Stringent Smoke Standards
1975 — CARB	— More Stringent Standards
1977 — CARB	↓
1979 — EPA	
1980 — CARB	
1984 — EPA & CARB	

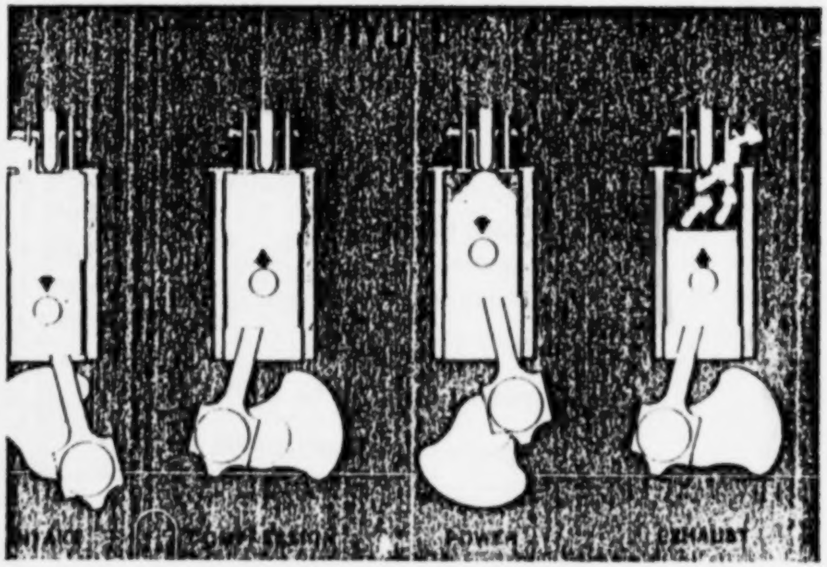
10

Government Regulations

11

COST
PRICE
VALUE

12


INTAKE
COMPRESSION
POWER
EXHAUST

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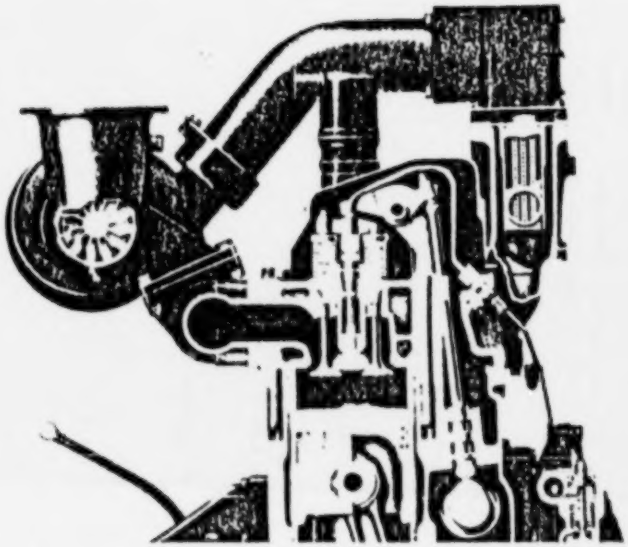

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Engine Modifications & Techniques Investigated To Reduce Emissions

- Turbocharger
- Compression ratio
- Crater shapes
- Valve timing
- Zero sac injection nozzles
- Aftercooling-jacket water
- Aftercooling-separate circuit
- Injection timing
- Higher pressure fuel injection
- Exhaust gas recirculation
- Cylinder cut-out at idle
- Torque rise limiting
- Damped nozzle checks
- Reduced cylinder dead volume
- Electronic control
- Injection spray angle, hole number & size
- Improved turbocharger efficiency
- Reduced engine displacement
- Reduced engine speed
- Combustion swirl rate
- Number of valves

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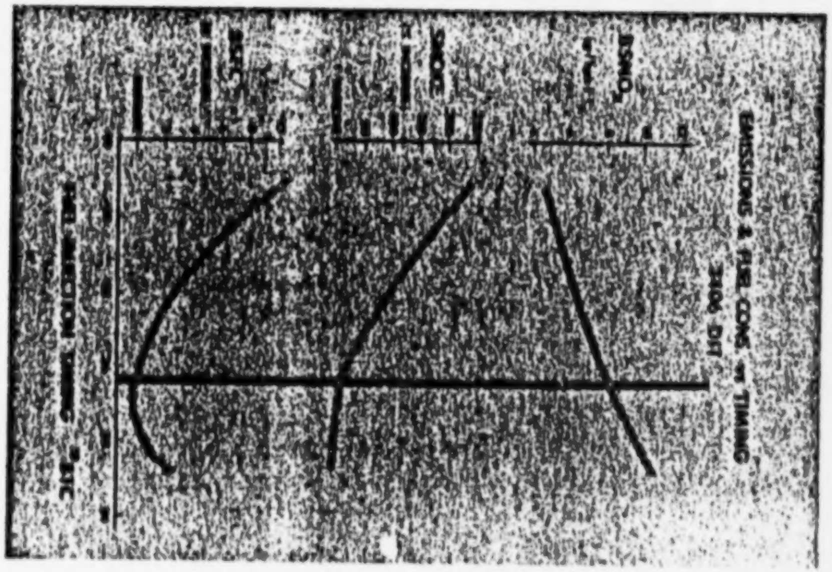

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Engine Modification Effect On Emissions

	HC	NO_x	Smoke	BSFC
Cool Inlet Air	▲	▼	—	▼
Low Sac Nozzle	▼	—	▲	—
High Comp. Ratio	▼	[illegible]	▲	—
EGR	▼	▼	▲	▲
Variable Timing (Speed Adv.)	▼	▲	▼	▼
Variable Timing (Load Adv.)	—	▲	▼	▼
Variable Timing (Load Ret.)	—	▼	▲	▲
Injection Pressure	—	—	▼	—
Min. Dead Volume	—	—	▼	—
Low Swirl	▼	—	—	▼

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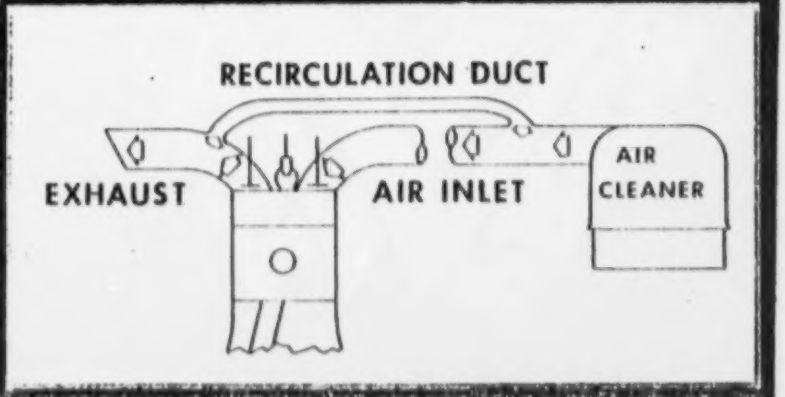
EXHAUST GAS RECIRCULATION



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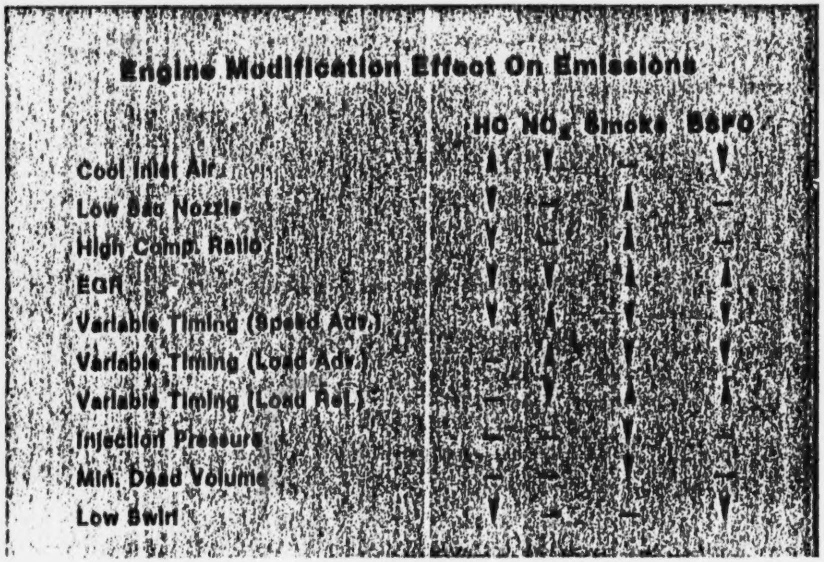

Engine Modification Effect On Emissions

	HC	NO_x	Smoke	BSFC
Cool Inlet Air	▲	▼	—	▼
Low Sac Nozzle	▼	—	▲	—
High Comp. Ratio	▼	—	▲	—
EGR	▼	▼	▲	▲
Variable Timing (Speed Adv.)	▼	▲	▼	▼
Variable Timing (Load Adv.)	—	▲	▼	▼
Variable Timing (Load Ret.)	—	▼	▲	▲
Injection Pressure	—	—	▼	—
Min. Dead Volume	—	—	▼	—
Low Swirl	▼	—	—	▼

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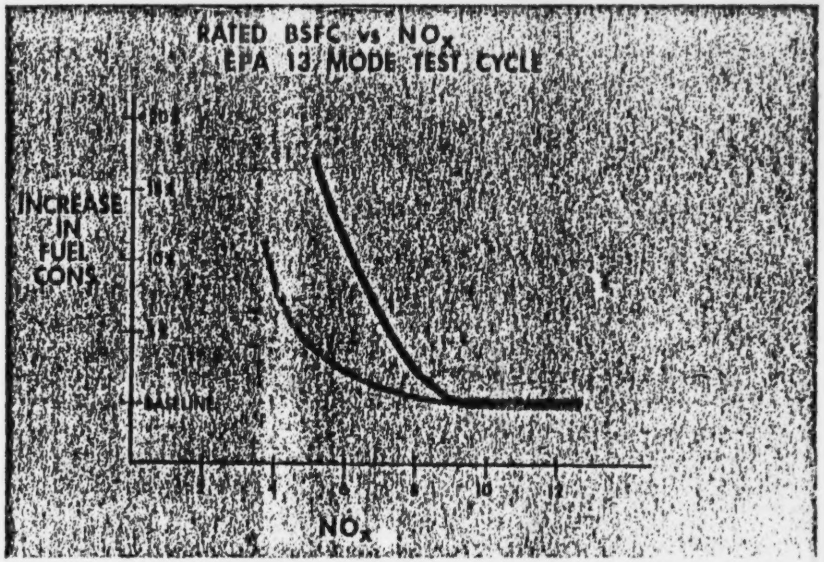

RATED BSFC vs NO_x
EPA 13 MODE TEST CYCLE

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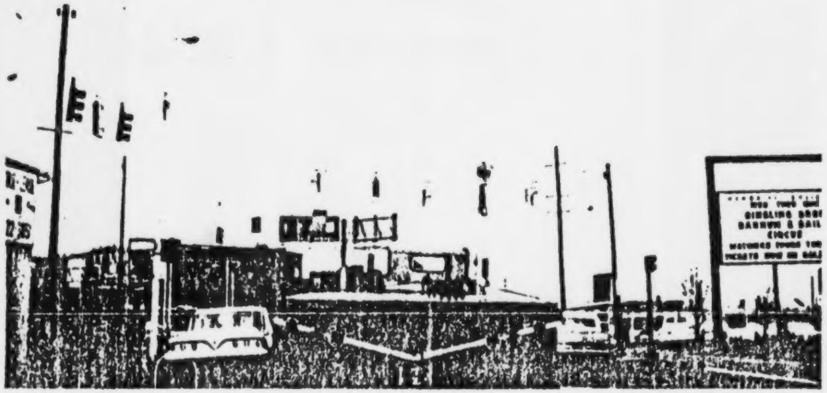

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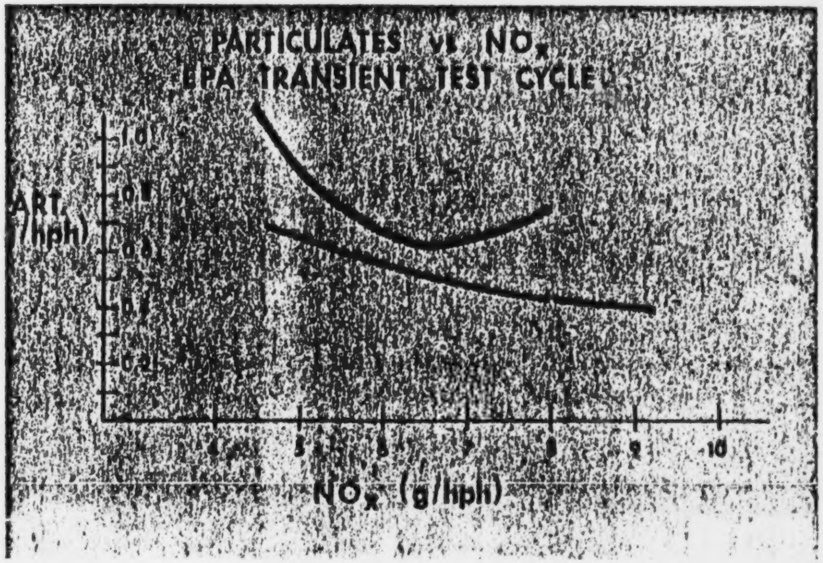

PARTICULATES vs NO_x
EPA TRANSIENT TEST CYCLE

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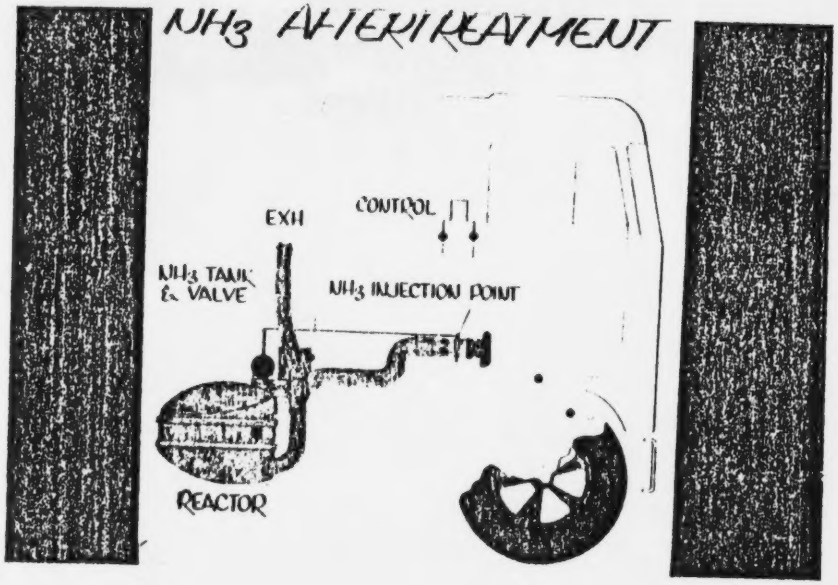

NH_3 AFTERTREATMENT

EXH
CONTROL
NH_3 TANK & VALVE
NH_3 INJECTION POINT
REACTOR

23

Particulate Aftertreatment

- Filter Media
  - Ceramic Honeycomb
  - Steel Wool
  - Steel Wool with Catalyst
- Container
  - Enclose Filter Media
  - Protect from Elements
  - Connect to Exhaust System
- Regeneration Control System
  - Cycle Time
  - Sensors
  - Maximum Temperature
  - Exhaust Bypass

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Heavy Duty Diesel Truck Engines

Emission Control Tradeoffs

- Fuel Consumption
- Cost
- Performance (Driveability)
- Particulates
- NO_x
- HC
- Reliability

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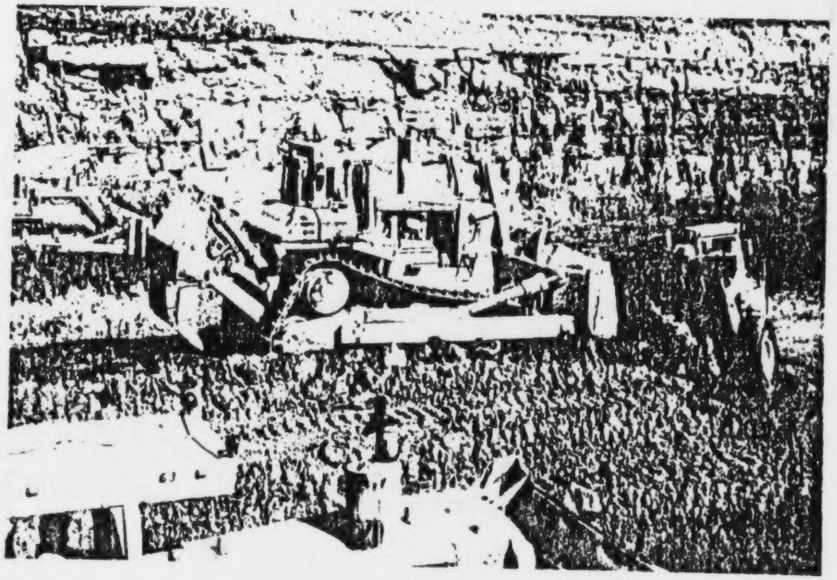

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Off-Highway Diesel Engine Uses

- Agricultural
- Construction
- Industrial

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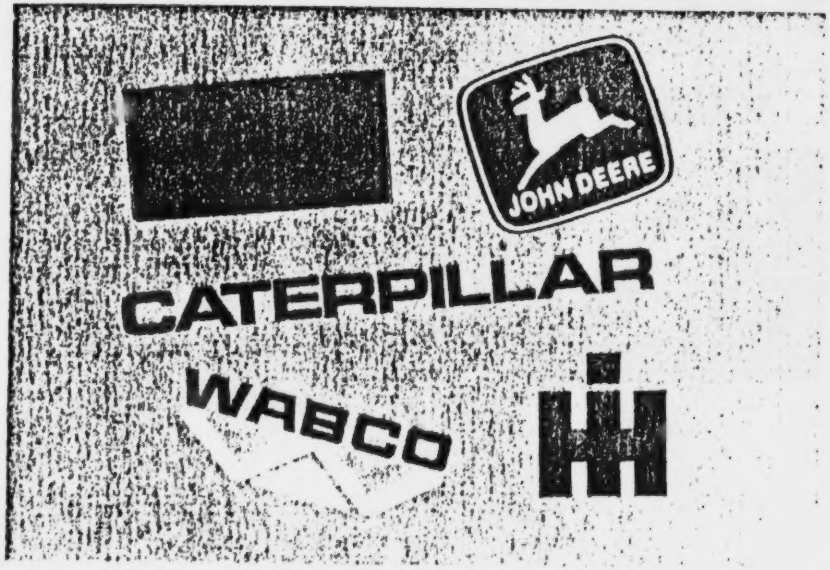
JOHN DEERE
CATERPILLAR
WABCO

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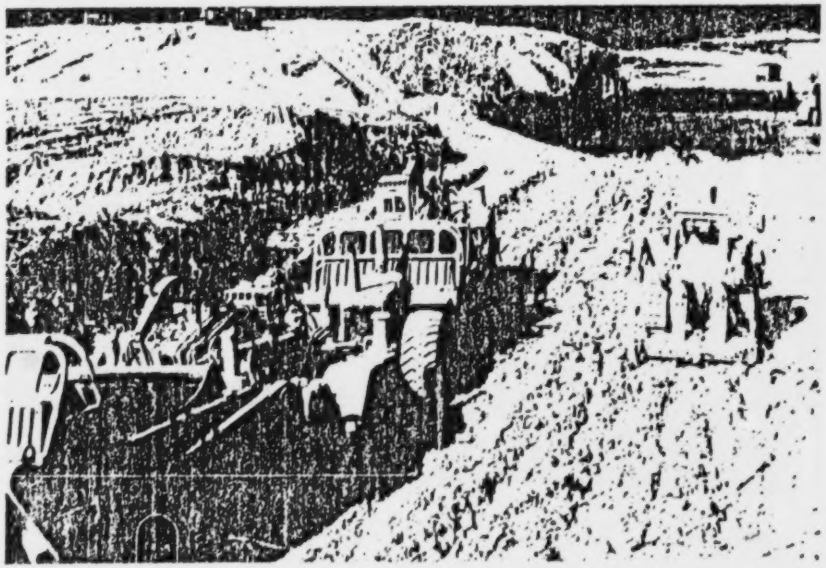

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Industry Study

- California Off-Highway Emissions
  - Farm Equipment
  - Non-Farm Equipment

30

Industry Study Objectives

- Collect Industry Emissions & Sales Data
- Assess Availability & Cost of Emission Control
- Evaluate Impacts on Air Quality

31

Off-Highway Engine Categories

- Engines Used Both On-Highway & Off-Highway
- New Off-Highway Engines
- Large High Horsepower Engines Used Off-Highway Only
- Off-Highway Engines Mfd. by Companies Not Producing On-Highway Engines

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Industry Study

Emission Control Technology for Off-Highway Engines

- Similar to that for On-Highway Engines
- NO_x Most Difficult to Control
- Off-Highway Engines have less Flexibility
  - Vehicle Designed for Specific Application
  - Integrated Power Train Design
  - Drive Train Options Not Available
  - Engine Performance Matched to Vehicle Vehicle Performance

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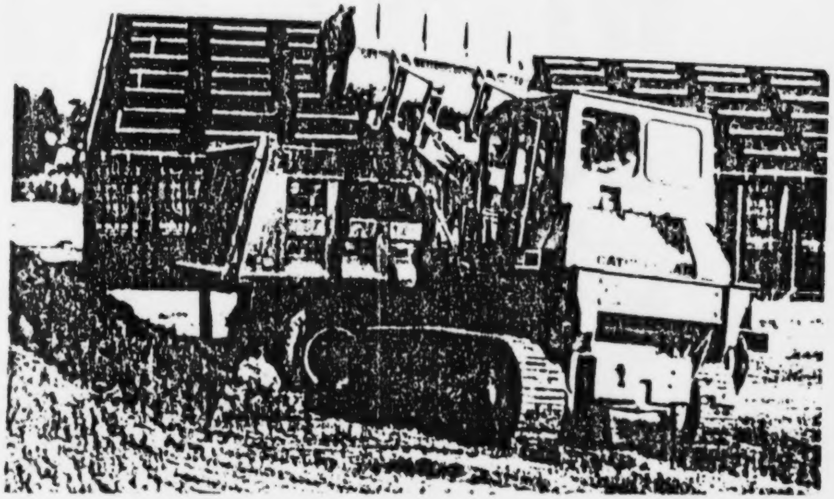

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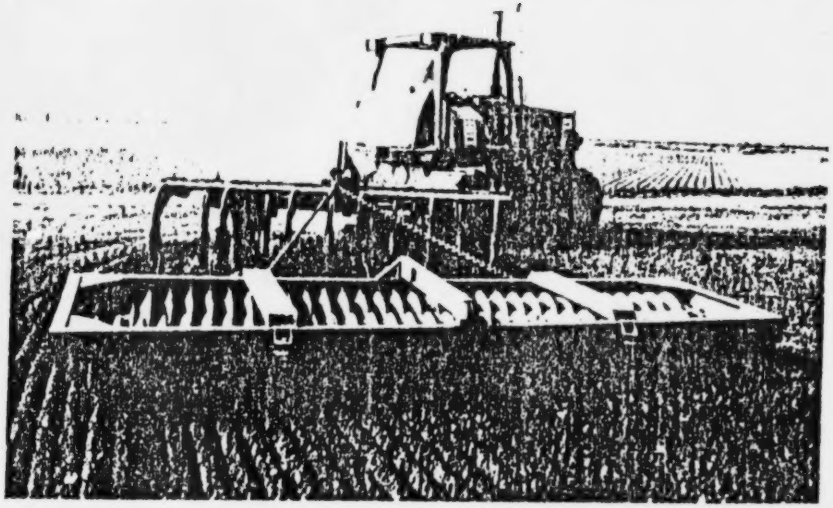

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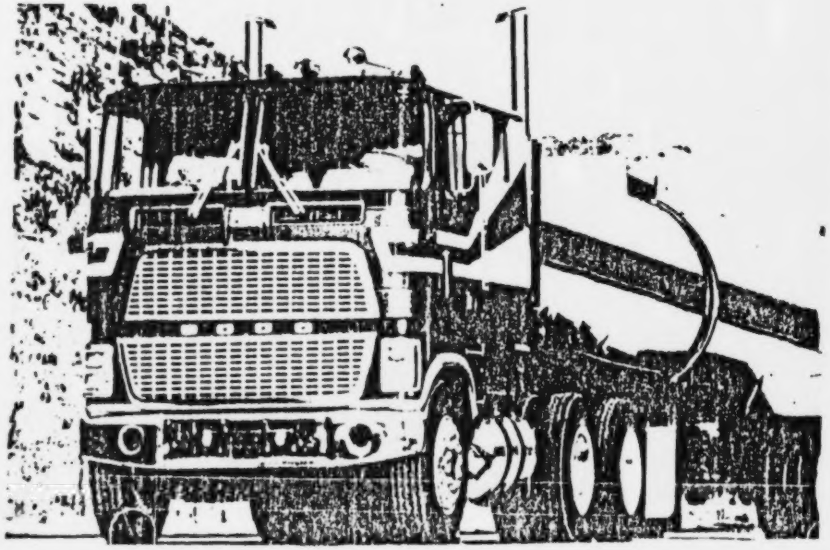

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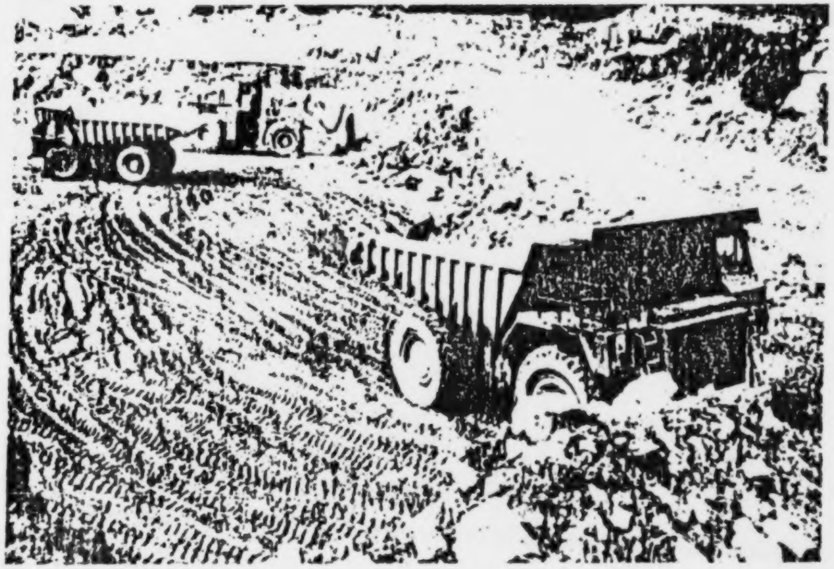

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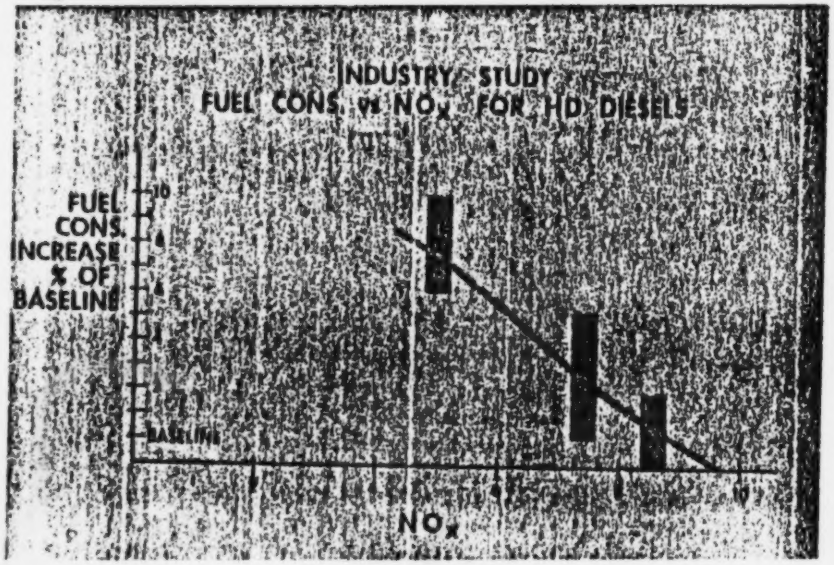

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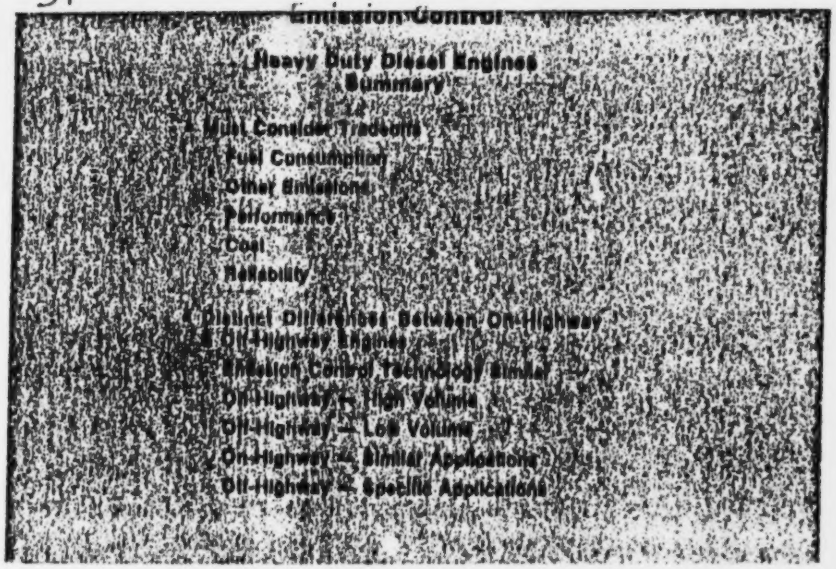
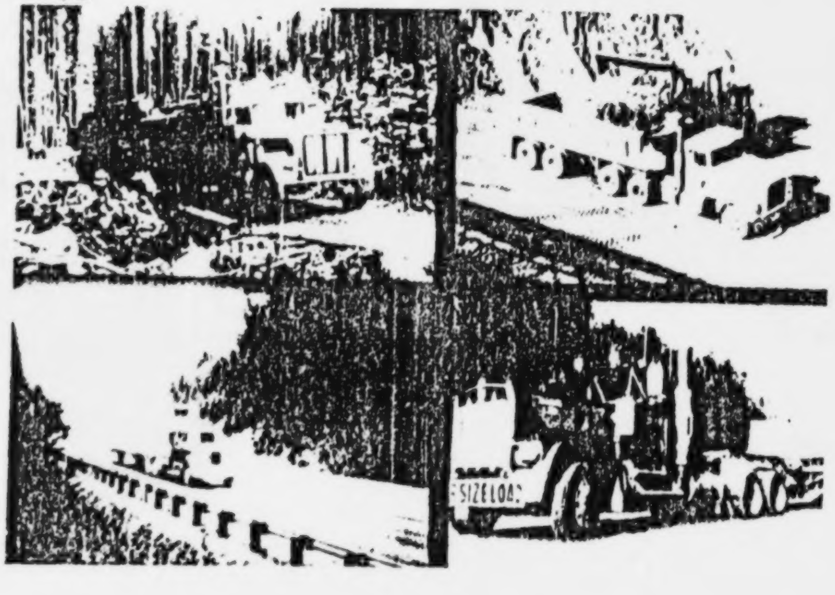


Emission Control

Heavy Duty Diesel Engines
Summary

- Must Consider Tradeoffs
  - Fuel Consumption
  - Other Emissions
  - Performance
  - Cost
  - Reliability
- Distinct Differences Between On-Highway & Off-Highway Engines
  - Emission Control Technology Similar
  - On-Highway — High Volume
  - Off-Highway — Low Volume
  - On-Highway — Similar Applications
  - Off-Highway — Specific Applications

40



DIESEL EMISSION CONTROLS:
CRYSTAL BALL GAZING

STAPPA Motor Vehicle Emissions Control Conference

Scottsdale, Arizona
May 6, 1982

W.S. Ansert, VWoA
Dr. R. Beckmann, VWAG
K.-H. Neumann, VWAG

Good afternoon, the topic for this afternoon is Current and Future Technology in Diesel Emission Control. But before we can get into that subject I believe it's wise to describe the framework of regulations which affects product development decisions in this area.

Basically there are two regulatory bodies having separate requirements for today's passenger car diesels. These are the EPA for federal control and the California Air Resources Board for California vehicles. Although most of you are not affected by the latter regulatory scheme it will help our discussion here if you have some basic understanding of that approach.

First I should state that I will be discussing both regulatory plans with regard to passenger vehicles, since that is more recognizable and most of the issues are the same for light duty diesel trucks under 6,000 lbs. Gross Vehicle Weight Rating (GVWR). For manufacturers of light duty diesel trucks above 6,000 lbs. GVWR there may be some different considerations which I will not address here.

Now that the ground rules are established let's start talking about the standards for light duty diesel vehicles beginning with the 1983 model year. I've chosen 1983 since our certification programs have already begun, precluding our ability to make any major changes without substantial cost penalties. For 1983 the federal standards which apply to light duty diesel passenger cars are .41 gram per mile

Hydrocarbons (HC), 3.4 grams per mile Carbon Monoxide (CO), and 1.0 gram per mile Oxides of Nitrogen (NOx). In addition to those gaseous pollutant standards there is a 0.6 gram per mile limit on particulate emissions and this standard, in combination with the NOx standard of 1.0 gram per mile will be a primary topic. For 1983 as well as 1984 there remains a provision in the Clean Air Act for EPA to waive the 1.0 gram per mile standard up to a maximum of 1.5 grams per mile upon a showing of certain statutorily defined criteria. In Volkswagen's situation our NOx standards range from 1.3 grams per mile to 1.5 grams per mile for 1983 and 1984 based essentially on the weight of the vehicle and the engine which is available in it.

In 1985, although the HC and CO standards remain the same, the NOx is statutorily required to go to 1.0 gram per mile with no waiver provision and the regulatory requirement for particulates drops from 0.6 to 0.2 gram per mile. There has been much debate in Congress about the need for this NOx standard and even more debate between EPA and Industry on the need for a lower particulate standard, however, I am only outlining here the standards which are currently on the books for the years I'm discussing. After 1985 the standards remain constant at .41 gpm HC, 3.4 gpm CO, 1.0 gpm NOx, and 0.2 gpm Particulate Matter.

California standards are really quite another issue. The standards in California for which a comparable Federal program exists are .39 gpm Non-Methane Hydrocarbons (NMHC), 7.0 gpm CO, and 0.4 gpm NOx.

California has adopted several optional procedures, the first of which would allow certification at 50,000 miles to a level of 0.7 gpm NOx if a manufacturer opts for some additional requirements including a specific recall program for 75,000 miles. Another more extensive option is a 100,000 mile certification option, requiring a 100,000 mile or 10 year warranty program with standards of .46 gpm NMHC, 8.3 gpm CO, and 1.5 gpm NOx for 1983. Currently the California Air Resources Board does not feel that it has sufficient information on particulates with regard to the California air pollution situation to require a separate standard and therefore has chosen to include the Federal 0.6 gram per mile standard as part of its enforcement program. Again, there has been considerable discussion and this may change, but these are on the books for the years in question. Unless things change for 1984, the most likely option all manufacturers would attempt for diesel certification will be .46 gpm NMHC, 8.3 gpm CO and 1.0 gpm NOx at 100,000 miles. VW is at this time uncertain of our ability to comply with such a standard in the field. The NOx and Particulates are the most critical to light duty diesels, however, HC occassionally becomes a problem as we'll see later.

I apologize for leading you through this maze of numbers, but I think it's important to properly describe what the manufacturer must take into consideration when developing his approach to emission controls. He must not only look at what is coming in the following year, but also the future. From this "crystal ball" he must determine what system will be effective in reducing emissions, durable in use, and economically feasible.

To refresh your memories, the diesel is a compression ignition engine which operates on the principle that when air is highly compressed its temperature rises. At a given point when the air is sufficiently hot, the fuel is injected and ignites without the aid of anything like spark plugs. The point here is that diesels operate on excess air, unlike a gasoline engine which operates best near stoichiometric air-fuel ratios.

With these things in mind, I'm going to describe two basic philosophies used to meet future emission standards. First is the use of, for lack of a better term, "external devices". These are devices used to clean up emissions on an engine, but not required for the basic purpose of the passenger car engine: that of providing power for a wide range of driving conditions. I think an example of this type of approach is that of the catalytic converter. A second philosophy, and one which Volkswagen is committed to, is that of combustion improvement. Under this system one alters the combustion process to meet the standards, durability requirements, and economic requirement by modifying or calibrating the basic engine components. This latter approach is not always available, since the practical limitation of a given engine design may render further modification or calibration impossible. When such a condition exists a manufacturer is forced to fall back to the "external" improvement until further developments in the combustion process can be accomplished. This concludes the background material and brings us to the first topic on the agenda.

CURRENT TECHNOLOGY

As noted, the basic VW approach to what we've just discussed is that of combustion improvements. Since approximately 1980 when the standards began to drop below the inherent emission levels of the diesel engine, VW has been involved in an extensive program to modify the diesel combustion process on our engines to meet applicable standards. Our first approach was to optimize injection timing which affects power, noise, and emissions of HC, NOx and particulates, until we were able to reach all of our objectives. As the standards continued downward, additional changes were required to the combustion chamber itself.

The "Schusskanal" or throat has been modified to provide better NOx control as well as some measure of particulate control in the small diesel engine. By reducing the throat area and increasing the swirl in the lower combustion chamber, a minute but consistent reduction in particulates was obtained at low engine load with somewhat less power available. The high load conditions with this modification show higher emission characteristics and the opposite phenomena occur when the throat is enlarged.

In addition, the "Spritzkanal" or injector pocket has been enlarged to cause better mixing in the prechamber and therefore a better combustion. The results of this modification were significant (about 20%) improvements in HC, NOx, and Particulates, but with a slight torque loss. This improvement combined with that of the Schusskanal gave sufficient emission reduction to our diesels to enable us to meet the current (1983) diesel emission standards. After the two improvements noted above had been made to the cylinder head, it was again necessary to optimize injection timing. This slide shows some of the complexities of attempting to optimize diesel injection timing. Note that retarding the injection timing generally reduces Particulates and NOx, however, it causes HC which is normally inherently low on a diesel engine, to increase almost 4 fold. This is the area where I mentioned earlier that HC can become a problem even though NOx and Particulates are the primary area of concern. Where these lines intersect the emissions have been minimized. Further consideration must then be given to any power loss or any increase in the noise levels.

As I already noted, the basic research on combustion combined with the calibration modifications noted above have permitted VW to meet the current standards with all of our vehicles. There are some limitations in the above approach, however, which create problems. First, these modifications provide very small benefits in terms of actual emission reduction. The second limitation is really two interrelated road today, if they have an EGR system, use the simple vacuum operated valve to control the amount of exhaust gas recirculation. There may be an orifice which controls the amount of EGR flow in these systems, but the concept is the same as the basic EGR introduced on gasoline cars in the early 1970's.

The amount of EGR is much more difficult to describe and control on a diesel engine than on its gasoline counterpart. The gasoline engine, being throttled, provides an inherent method for control of the exhaust gas flow into the intake section of the engine for EGR. The control systems which have been used to accomplish this task relate to the vacuum available in the intake manifold (to operate the EGR valve and to help create gas flow) and the exhaust gas backpressure. Since, for a gasoline engine, there is a great difference in the absolute pressure between the exhaust and the intake, there is relatively consistent control within the engine itself. The diesel, on the other hand, does not have this luxury. Because the diesel is an unthrottled engine, there is no manifold vacuum with which to control the operation of an EGR valve itself. This has been solved on most vehicles by means of an additional vacuum pump in the accessory drive system which provides vacuum for multiple uses (including accessories as well as EGR valves).

The remaining problem related to this unthrottled condition is that the inherent control in the gasoline engine due to the relatively great problems: weight and power loss. The weight of the vehicle in which the engine is installed has a significant effect on its NOx emission levels. This is due to the fact that an engine of a given size must be run at a higher load condition to provide normal operation when it is installed in a heavier vehicle.

The other problem is that, even though these are combustion improvements from the standpoint of emissions, there may be some power loss due to the optimization of injection timing or throat size or injector pocket dimension. That is to say that by optimizing for emissions one may have a power loss across a significant portion of the engine power curve. If such a loss is too great it may affect product decisions involving engine selection for particular vehicles.

The other major philosophy for emission reduction in diesels involves the addition of specific devices whose sole purpose is to reduce a given emission constituent. These are, at this time, limited to varying types of EGR. With current technology for the larger engines this may be the only method to reduce NOx to levels below 1.0 gram per mile. Current technology in this area is relatively basic. Although some people have experimented with electro-pneumatic and electronically controlled EGR systems, the majority of diesel passenger cars on the pressure differential between exhaust and intake is not available in a diesel. The only purpose for an intake system on a diesel is to provide clean air at a rate demanded by the speed and load characteristics. The air must be distributed relatively consistently among all cylinders. Those are the only requirements for the intake system and there is not a high vacuum in the manifold. This lack of pressure differential between intake and exhaust means that EGR is more difficult to monitor and control without adding complexity to the EGR system.

Going from the theoretical to the practical side, the inclusion of EGR results in a higher particulate emission from the engine itself. The increase in particulates causes a number of problems relating to the durability of the diesel engine. These problems include coagulation of the oil, contamination of the oil, and an increasing combustion deposit and wear characteristic because of the introduction of diesel exhaust particles back into the combustion chamber. Volkswagen has also noted a deterioration of driveability when the EGR is installed which becomes critical when evaluating small displacement diesels. Our diesel has about 28% less power than our gasoline engine of the same displacement. Any loss of part throttle driveability coupled with this lower power is therefore unacceptable.

This leads to the conclusion that EGR, if it is to be used on an engine, will require a much finer control mechanism than the normal vacuum and exhaust backpressure techniques, so that the recirculation is present only in amounts which are acceptable to particulate emission, power, and engine durability requirements. There are systems being evaluated which may provide this additional control at some time in the future. One of the most promising systems for this more precise EGR control involves the use of electronics. This leads us to my final topic for this afternoon which is future technology.

FUTURE TECHNOLOGY

This is where the real "crystal ball gazing" begins. Technology for use with diesel emission controls appears to be developing in two particular areas with some promise. These two areas, electronics and particulate trap technology, may provide at least a partial solution to emission control problems in the near term. By near term I mean within approximately 5-10 years.

First, let us discuss electronics. One of the most talked about possibilities in the area of diesel emission control is that of electronically controlled fuel injection. What this system would provide is a much more precise control of the injection and therefore the combustion process in the diesel engine. This is true because of the importance of injection timing and duration on the combustion in a diesel. Essentially, we are talking about providing the engine with the correct amount of fuel at the correct time for the proper duration of stroke to minimize harmful pollutants from the diesel without severely restricting other areas of the power curve.

Problems in this approach are the development of reliable sensors which interface between the mechanical aspects of the engine and the electronic logic which would have to be installed in the vehicle. The advantages of this type of system are in the better control of the combustion process. Obviously, this system will cost more, because of the additional higher technology hardware that would have to be included.

Although much less discussed, certainly more important in the shorter term is that of electronic controls on any EGR system to be used. VW has a particular problem with EGR in this area and has evaluated a prototype electronically controlled EGR system. The most difficult problem to overcome is the matter of interface between the accelerator lever position for the diesel and the logic used to control input to the EGR valve. Accelerator lever position on the Bosch type VE pump does not solely determine the volume of fuel delivered to the combustion chamber. This particular pump has a spring loaded governor mechanism which is load sensitive and can deliver varying fuel rates depending on the engine speed at a constant accelerator position. It is therefore difficult to provide the logic for input to the EGR valve based strictly on accelerator position.

A further note is that the full benefit of an electronic EGR system can only be realized if there is the accurate input to the combustion chamber of the electronic injection system. In other words, while we are investigating these systems separately, their full benefit will be realized only when they are used in conjunction with each other.

A prototype electronic EGR system has been developed which demonstrates some reduction in NOx emission without great increases in particulate emission, but I must stress that the system as used on the prototype is infeasible for production at this time. The problem has to do with the accuracy of sensing accelerator position and we are attempting to resolve that without increasing the already high anticipated cost of approximately $340 per vehicle.

Next, I'll discuss particulate traps. Particulate traps have been foremost in the minds of both EPA and the CARB recently and perhaps a general discussion of the historical development is appropriate. I'm going to discuss this only from the VW standpoint so that you get the perspective of one manufacturer's problems in the development of new technology.

When we first brought the diesel engine into our vehicles in 1978, there was already some concern about particulates emitted from diesel engines. First, some filters were adapted to production vehicles to determine if these particles could be removed by changing filter canisters, much the same as is done for oil filter canisters during a normal maintenance interval. It was determined that this method was unacceptable due to the high frequency of changes needed, high backpressure in the exhaust system, and the concern that customers omitting this maintenance in an attempt to save cost might subsequently cause engine failure. The next step involved the investigation of filter materials which would regenerate themselves by burning off the particulates which had been trapped in the substrate. More significant problems arose in this area, since the trapped particulates required some specific conditions in order to ignite and once the ignition occurred the combustion was uncontrolled. The result was either plugged or melted traps and, in the extreme case, a vehicle fire. That stage of technological development was reported at the EPA hearings on particulate standards for diesels. Further evaluation has provided us with information on the reasons for these problems and we are now working toward solving them.

VW has contracted with Ricardo to work on the problems of particulate traps with some important results. Initially it was determined that catalytic material on the trap substrate could lower the ignition temperature of the particles. This gave us better control of the "regeneration" or burn off. The problem then remained that the type of driving required to start this regeneration is not encountered in normal driving.

What is shown here is an engine exhaust temperature map showing the lines of constant temperature or isotherms at various load and speed conditions of a diesel during engine operation. The yellow area in the lower left hand section of the map describes the area of engine operation within which the Federal Test Procedure falls. The one further piece of information to help you understand the difficulties of regeneration in trap technology is that under normal circumstances the regeneration process requires an input temperature of approximately 550°C. for 5-10 minutes of operation. As you can see, operation on a Federal Test Procedure, which is to represent normal vehicle operation, does not allow for such regeneration. If this occurred in the field the result would be a lot of plugged or melted traps.

Therefore, it is necessary to develop some device or procedure which will create the conditions necessary for regeneration. The most recent attempt, was that of a Johnson Matthey trap equipped Diesel Rabbit. The car has completed 50,000 miles at Southwest Research Institute in a study funded by Johnson-Matthey at levels below 0.2 grams per mile particulates. The car was equipped with a manually activated regeneration device which maladjusted the injection timing in the engine for a period of time long enough to raise exhaust gas temperature and begin the regeneration process. It should also be noted that production diesel Rabbits on the average currently exhibit results of particulates in the area of .25 gram per mile with no trap oxidizer. It is the heavier cars with larger engines and greater throughput which will have a greater need for trap technology if a 0.2 gram per mile standard is put into effect. Engineers at Corning Glass Works, another producer of filter substrate materials, have estimated that collection efficiencies between 50 to 90% may be necessary for larger vehicles to meet the 1985 particulate standard. The Johnson-Matthey car had a trap efficiency of approximately 30% during this test. That's better than in the past, but not good enough yet for the majority of vehicles which will need this technology.

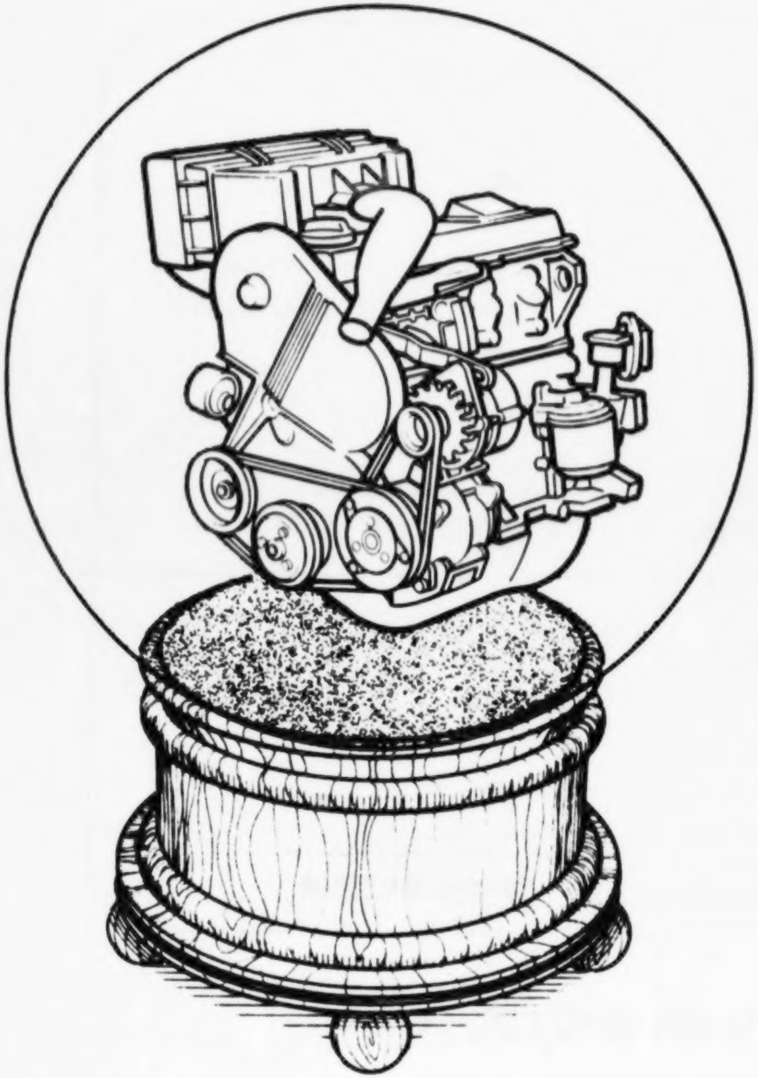
Finally, an area which we have not discussed yet is that of the "future technology" in determining what the health effects of these pollutants are and what the proper standards should be. Even now standards are being set based on technological feasibility questions rather than established health effects criteria. Frankly, it is our opinion that the industry and government have been operating independently to determine the health effects of automotive exhaust components for too long and that a cooperative effort to put to rest the turmoil in this area would be extremely beneficial to both sides.

Summarizing what I have discussed, I think the following points are of importance:

- Volkswagen has taken the approach in preparing its vehicles to meet emission standards that it is much better to alter the combustion and improve the combustion process for emission reduction rather than to add on devices whose specific function is to reduce emissions. This philosophy can only be continued so long as standards are reasonable and market demands are not such that larger engines are required.
- Technology in the area of electronic fuel management and electronic EGR is progressing to a stage that it may be available within the next 5 years. The basics for each of these systems has been demonstrated, however, issues of adaptability to the automotive environment, durability and cost effectiveness still need to be addressed.
- Particulate traps have now progressed to the point that they may be available within 5 to 10 years.
- In each of these cases, except basic engine technology, we are extremely dependent on suppliers. Therefore, since we aren't in control of our own destiny, we are somewhat skeptical about projections of others concerning availability of this technology.
- Health Effects must be adequately researched and reported to determine where technological resources should be concentrated for future development.

Hopefully, we can all work together on these areas and improve the U.S. position in the world market place as well as improve the air we breathe.

Thank you.



DIESEL EMISSION CONTROLS:

CRYSTAL BALL GAZING

K.-H. NEUMANN
DR. R. BECKMANN
W. S. ANSERT

VOLKSWAGEN

EMISSION STANDARDS

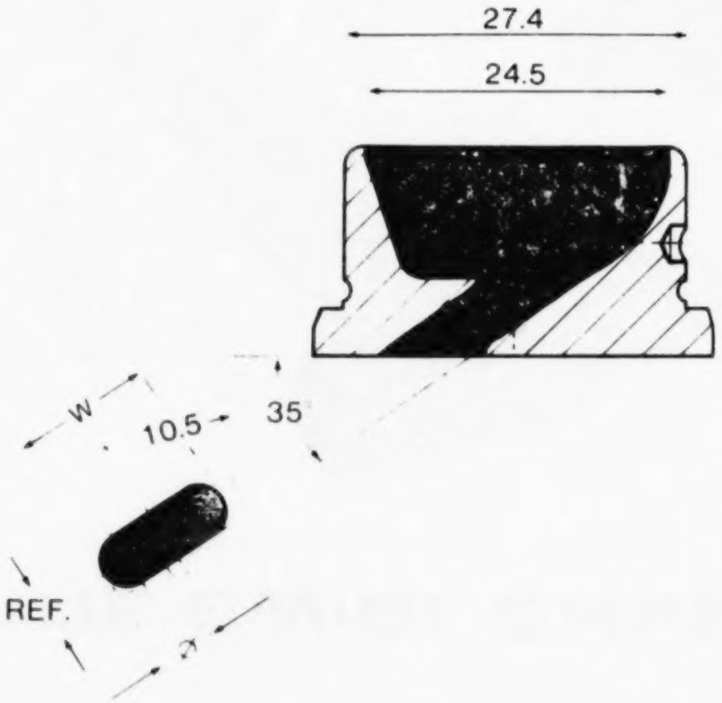
FEDERAL		CERTIFICATION OPTION	1983	1984	1985 & BEYOND
EMISSIONS g/mi	HC	50,000	0.41	0.41	0.41
	CO	50,000	3.4	3.4	3.4
	NOx	50,000	1.0*	1.0*	1.0
	PARTICULATES		0.6	0.6	0.2

CALIFORNIA		CERTIFICATION OPTION	1983	1984 & BEYOND
EMISSIONS g/mi	HC	50,000	.39 (.41)	.39 (.41)
		75,000	.39 (.41)	.39 (.41)
		100,000	.46	.46
	CO	50,000	7.0	7.0
		75,000	7.0	7.0
		100,000	8.3	8.3
	NOx	50,000	0.4	0.4
		75,000	0.7	0.7
		100,000	1.5	1.0
	PARTICULATES		0.6	0.6

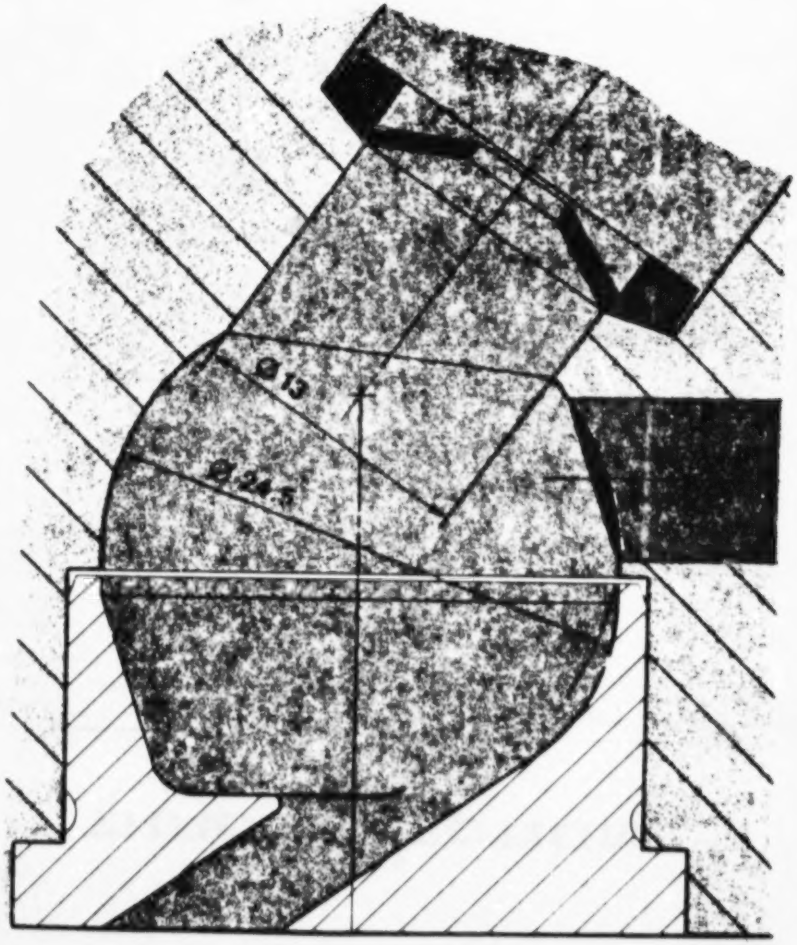
*FEDERAL WAIVER AVAILABLE TO 1.5

THROAT SECTION

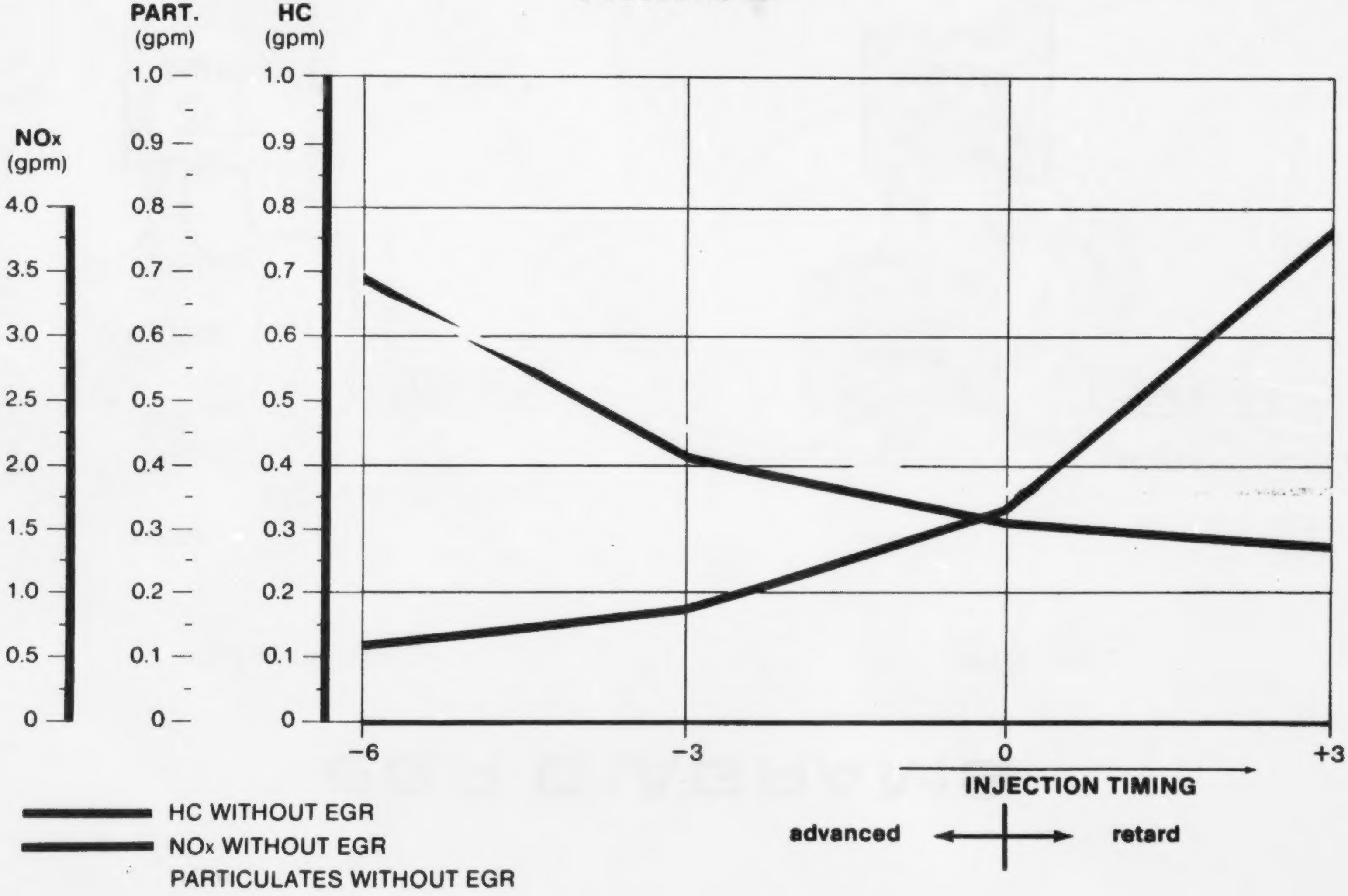
THROAT	AREA (cm^2)	W (mm)	Ø (mm)	REF (mm)
STANDARD	0.44	11.00	4.00	4.75
+18%	0.52	11.26	4.76	5.40
+30%	0.57	12.00	4.76	5.60


27.4
24.5
W
10.5
35°
REF.
Ø

1.6 LITRE SWIRL CHAMBER

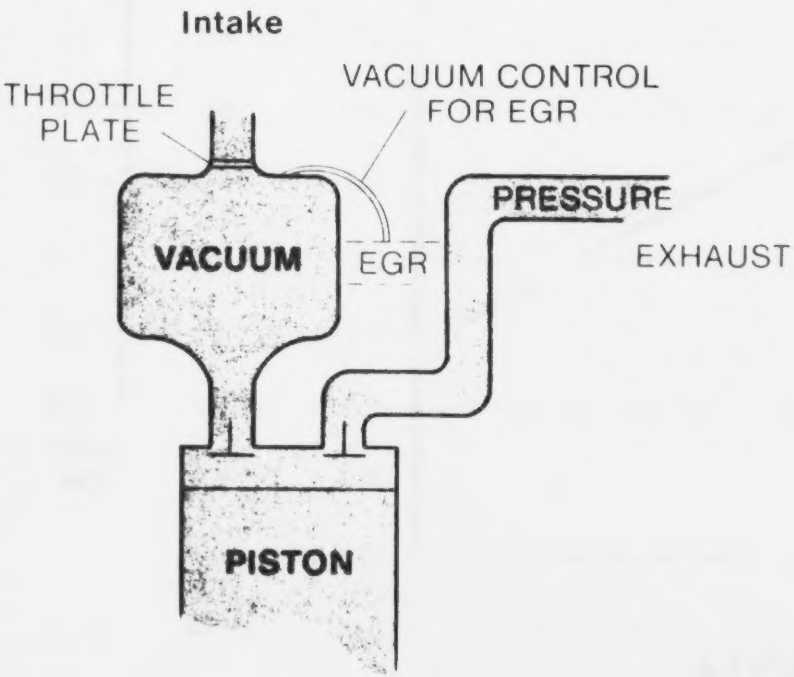


OPTIMIZATION OF INJECTION TIMING

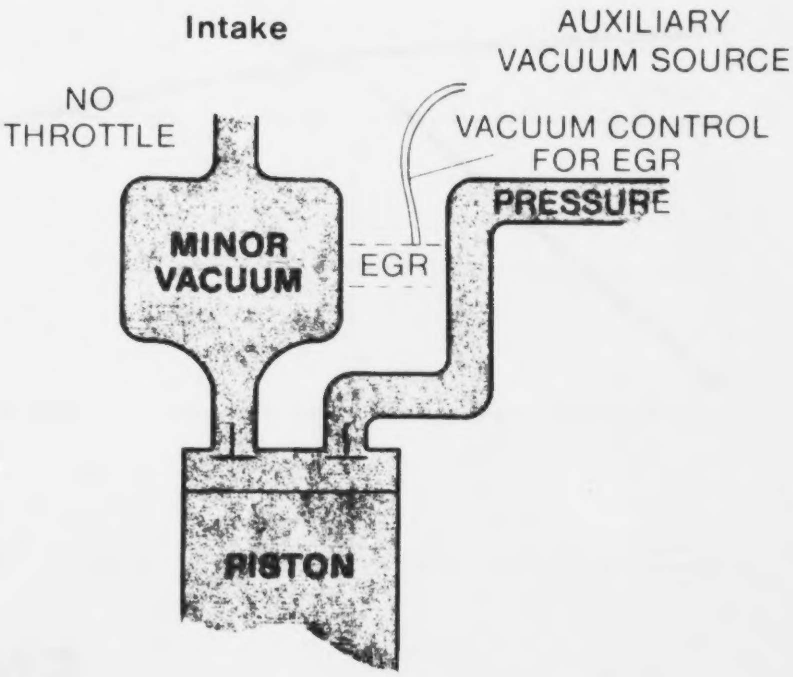


EGR DIAGRAMS

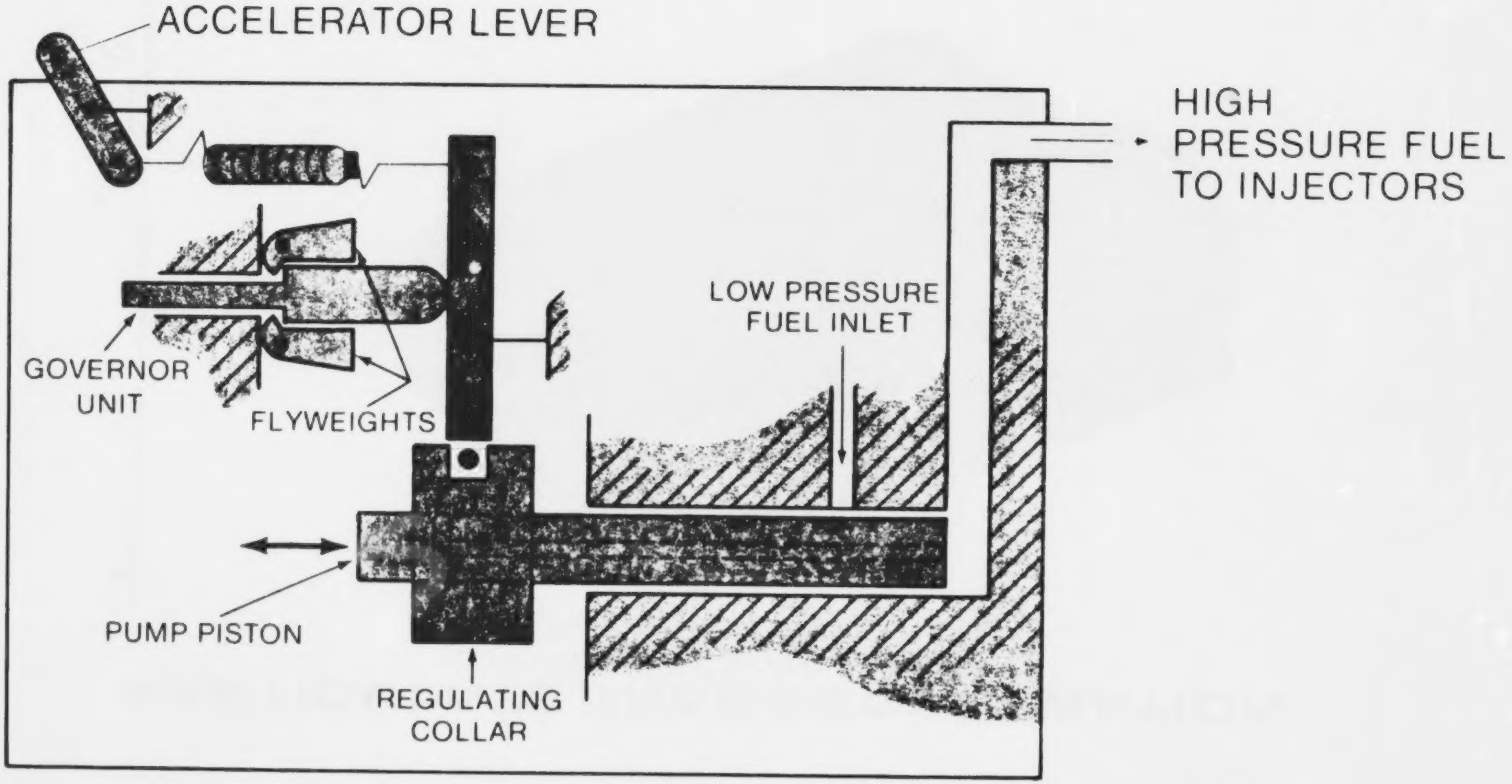
GASOLINE


Intake
THROTTLE PLATE
VACUUM CONTROL FOR EGR
VACUUM
EGR
PRESSURE
EXHAUST
PISTON

DIESEL

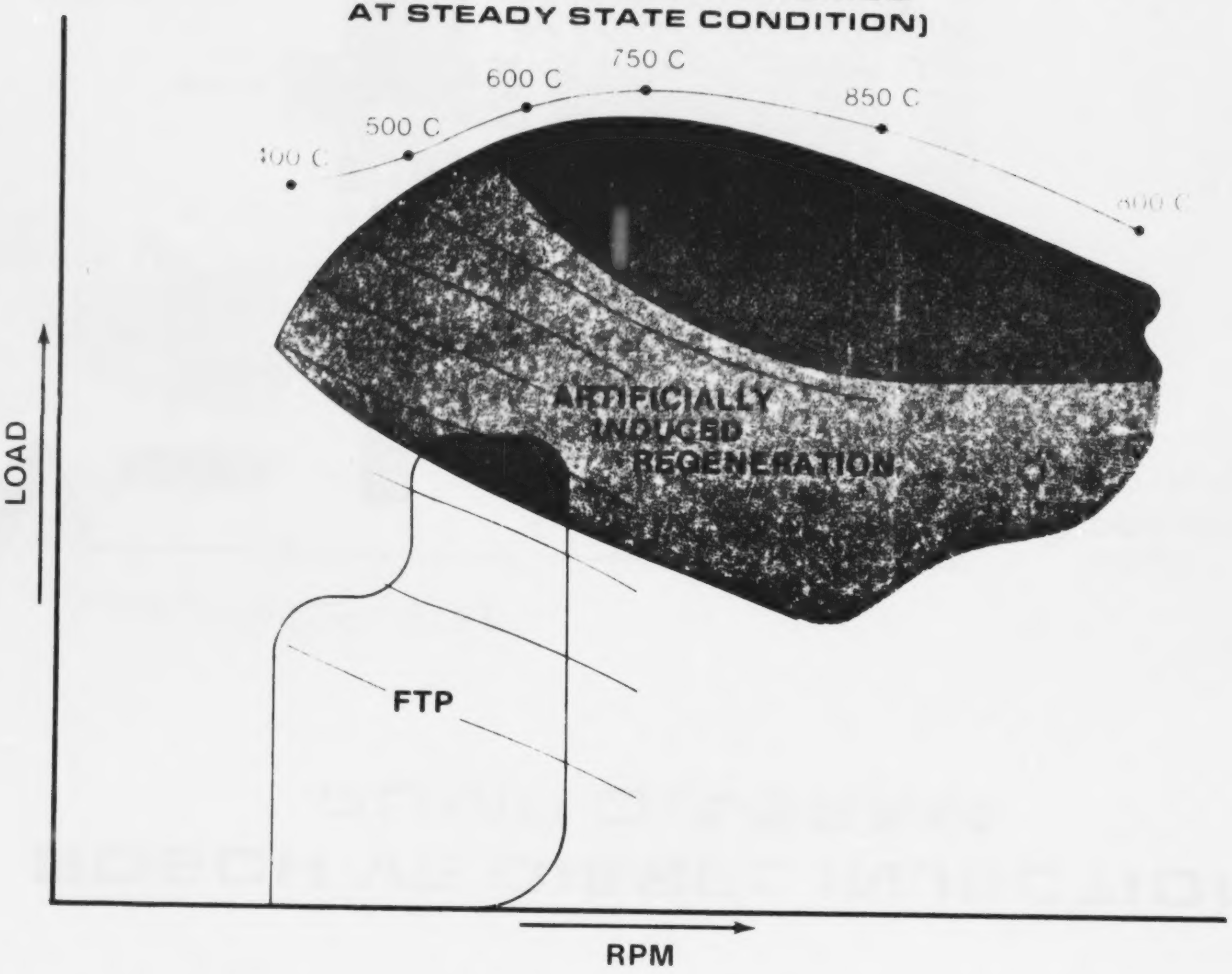

Intake
NO THROTTLE
AUXILIARY VACUUM SOURCE
VACUUM CONTROL FOR EGR
MINOR VACUUM
EGR
PRESSURE
PISTON

BOSCH VE DIESEL INJECTION PUMP DIAGRAM


ACCELERATOR LEVER
HIGH PRESSURE FUEL TO INJECTORS
LOW PRESSURE FUEL INLET
GOVERNOR UNIT
FLYWEIGHTS
PUMP PISTON
REGULATING COLLAR

PARTICULATE TRAP REGENERATION

(DURING 20-MINUTE PERIOD
AT STEADY STATE CONDITION)



SUMMARY

- COMBUSTION IMPROVEMENTS ARE PREFERABLE TO USE OF "ADD-ON" EMISSION CONTROL DEVICES.
- ELECTRONIC CONTROL TECHNOLOGY MAY BE ADAPTABLE WITHIN 5 YEARS.
- PARTICULATE TRAP TECHNOLOGY MAY BE ADAPTABLE WITHIN 5 - 10 YEARS.
- RELIANCE ON SUPPLIERS DETERMINES RATE OF PROGRESS.
- HEALTH EFFECTS RESEARCH IS NECESSARY TO FOCUS ON **REAL** PROBLEM AREAS.

Motorcycle Exhaust Emissions

Roger F. Hagie
Government Relations Manager
Kawasaki Motors Corp., U.S.A.

I'll begin today by making what on the surface seems to be an altogether obvious observation, but one which actually merits some closer examination; and that is: "A Motorcycle Is Differ-Than An Automobile". Nothing too revolutionary hiding in there, I trust. Yet this difference, or perhaps it is more correct to say these differences, assume what manufacturers feel to be very significant proportions in the application of exhaust emission control to motorcycles.

Some of the differences between motorcycles and autos are very obvious, and others are a bit more subtle. I'll get some of the obvious ones out of the way first: Motorcycles have fewer wheels. Motorcycles are smaller. People sit on motorcycles, rather than in them. Automobiles have "envelope" bodies, motorcycles do not.

What these factors have to do with emissions control is packaging; or, a place for everything and everything in its place. The essential character of the motorcycle is that it is small, some obviously being smaller than others, but all of them basically space-limited vehicles. Exhaust emission controls were developed on autos where overall size, and space utilization, were not critical concerns. Even weight reduction, the current darling of automakers, was the exclusive province of cottage cheese marketing people when auto emission controls were taking shape. Automobile emission control techniques and hardware are often just not applicable to motorcycles.

The motorcycle, by virtue of its two-wheeled stance, must be balanced in operation and leaned and guided around corners. This requires that the motorcycle be small enough, and light enough to be guided and balanced by the non-power assisted skills, strengths and reflexes of the rider. In general, the bigger, heavier or bulkier the motorcycle, the harder it is to balance (particularly at low speeds) and to ride.

The smaller size of the motorcycle of course places physical limits on the amount of equipment which can be carried, thus the motorcycle designer must avoid adding-on of equipment or components whenever possible. Also of critical importance is the location of the mass of the motorcycle. In general, items of large mass such as the engine and transmission unit and battery must be located as close to the center of the motorcycle as possible. Any mass located toward the motorcycle extremeties, away from the center of gravity, can produce less desirable handling characteristics.

Weight and mass then, are the enemy.

This tends to preclude adoption of add-on oriented techniques to control emissions.

The lack of an all enveloping body on a motorcycle (which is not, by the way, an oversight) means that virtually all of the componetry is exposed to view and thus must be styled and finished accordingly. As an example, consider the lowly exhaust system. On an automobile, a thing of no beauty whatsoever, crude castings, rusty pipes, ugly stamped mufflers and "industrial styled" catalytic converters. A motorcycle exhaust system, on the other hand, if not actually a thing of beauty and a joy forever, is potentially one of the dominant styling elements of the vehicle. Often chrome plated from one end to the other,it makes visual statements to the rider/buyer in the way it sounds, the way it curves back from the engine, in the way the outlet is styled, in the angle that it describes as it swings rearward. You may laugh, but these things have significant meaning to the motorcyclist, who has no hesitation to toss the stock exhaust system, lock, stock and muffler, in a corner of the garage and replace it with one that more eloquently makes the desired statement.

The concept just presented, that the motorcycle makes certain statements on behalf of its rider, is crucial to understanding the design and marketing of motorcycles. It is also one of the more subtle differences between motorcycles and automobiles which were referred to earlier.

While the automobile is largely moving towards a utilitarian form of transportation, with some emotional attachment remaining from the 50's and 60's, the motorcycle serves less as a form of point A to point B conveyance and more of a personal expression that the rider feels he is making about himself.

In this regard the motorcycle rider often seeks to personalize his vehicle with accessories or modifications that make the vehicle better suited to his needs. The touring rider may fit a complex system of fairing and luggage carriers, radio, tape player, CB, a different seat, additional lights, cruise control and much more. The sporting rider may go the opposite direction, removing components that are not essential to the sporting nature of the motorcycle, making engine and suspension modifications in hopes of improving the performance of the vehicle.

Most motorcyclists are not the least bit intimidated by the mechanical workings of their vehicles and many tend to be relentless tinkerers, freely changing and modifying until their particular combination suits them just right.

There are, of course, motorcyclists who view their vehicles as transportation only and who are little concerned with appearances and "statements". Such an attitude is clearly a minority one in the motorcycle marketplace.

A motorcycle certainly operates differently than an auto, and at least one automotive operating characteristic (which accompanied early emission controls) could be a major problem and conceivably dangerous for a motorcycle. In particular the tendency for engine stalling while warming up could pose a risk to the motorcycle operator. When an automobile stops unexpectedly its stability is not threatened; a motorcycle's could be.

Thus the motorcycle manufacturer strives to meet exhaust emission limits without using add-on components, without altering the motorcyclist's perception of the motorcycle, without adding too much weight, or cost, or size.

Some of the techniques that are being employed will be described later, but first a little history.

History of Motorcycle Emission Controls

Prior to about 1965 the motorcycle marketplace consisted mostly of large road-going models produced by American and British and European firms, and a few lightweight motorcycles and scooters. Sales were about 300,000 units per year. Beginning in the late 60's the Japanese manufacturers began selling motorcycles in the U.S. in earnest. They concentrated their products in the small to medium size range (compared to the large bikes from American and European manufacturers) and found a large, previously untapped market. By 1975, motorcycle sales in the U.S. had jumped to 750,000 units per year, with an estimated 5,000,000 motorcycles registered.

For the years just prior to 1975 the total number of motorcycles in use was increasing at about 10% per year leading to predictions of 10 to 12 million motorcycles in use by 1985. This extraordinary growth of the motorcycle market, "fueled" in part by the lack of fuel in 1973 and 1974 made the motorcycle a likely target for exhaust emission control.

As a sidenote I will add that the growth predictions proved highly inflated; in fact the industry has experienced some years of no-growth or decline since 1975, and current estimates put the number of motorcycles in use in the U.S. at about 6,000,000. By comparison, there are roughly 130-150 million passenger cars in use at present, or 22 to 25 cars for each motorcycle.

Nevertheless, motorcycles by 1975 looked like a likely target for exhaust emission control. In fact the EPA, in a 1973 transportation control plan, proposed placing strict ceilings on the sales of new motorcycles and a ban on two-stroke motorcycle operation during daylight hours from May through September in parts of California. It is not necessary to hit the motorcycle industry in the head with a 2 x 4 to get their attention: representatives of some of the motorcycle manufacturers went to Eric Stork at EPA and asked for regulations as an alternative to the sales ceilings and useage ban. EPA, of course, was only too happy to oblige.

EPA's regulations, which were intended primarily to assist the state of California, were proposed in 1975 and adopted in 1976. In the meantime, the California Air Resources Board, professing doubt that EPA would adopt motorcycle emission standards in a timely manner, adopted standards of their own which closely paralleled the EPA standards.

These original standards set limits for hydrocarbon at 5 grams per kilometer for small-engined motorcycles, 14 grams per kilometer for the large-engined models. For the medium sized models, a sliding scale standard between 5 and 14 grams was established based on engine displacement. A carbon monoxide limit of 17 grams per kilometer was set for all models.

These limits must be considered in light of the vehicle mix which existed in the motorcycle marketplace at the time. Unlike pre-emission controlled automobiles, which were offered almost exclusively with four-stroke engines of 8, 6 or 4 cylinders, motorcycles at the time were available in 1,2,3 and 4 cylinder four-stroke configurations and 1,2 and 3 cylinder two-stroke designs. The range of engine displacements in motorcycles ran from under 50 to over 1200 cubic centimeters (3 to 72 cubic inches) compared to about 75 to 450 cubic inches for automobiles.

The difference in engine types, two-stroke and four-stroke, is certainly one of the most significant factors in examining the pre-emission control motorcycle. Two-stroke engined models accounted for nearly 50% of the motorcycles sold in 1975, and a number of manufacturers (including one large manufacturer) offered only two-stroke models, while other manufacturers had just begun adding four-stroke models to their predominantly two-stroke line-up.

The two-stroke engine is a marvelous device for a lot of reasons. Emission characteristics (especially HC) are not one of them. The two-stroke engine operates on a rather significantly different principle than the four-stroke, and in fact was patented about 12 years after Nicholaus Otto patented his four-stroke design as a way of circumventing Otto's patents.

The familiar four-stroke design uses a system of valves, which are driven indirectly by the crankshaft, to regulate the passage of fuel and air into the engine and of combustion products out of the engine. This basic operation is illustrated by figure 1. As the piston starts its downward stroke, the intake valve opens and the fuel/air mixture is drawn from the intake manifold into the cylinder. This is appropriately enough called the intake stroke. As the piston reaches the bottom of its stroke the intake valve closes, sealing the fuel/air mixture in the cylinder. Then the piston rises in the cylinder, compressing the fuel/air mixture trapped above it. This, of course is the compression stroke. As the piston nears the top of the compression stroke the spark plug fires and ignites the mixture in the cylinder. The mixture burns, heats and expands quickly, pushing down on the top of the piston as it travels back down the cylinder. It is the force of the burning, expanding gasses pushing down on the piston during this combustion (or power) stroke that actually gets the work done. Finally, as the piston starts back up the cylinder the exhaust valve opens and the burned gasses are pushed past the open valve and out to the exhaust system. As the piston nears the top of the cylinder the exhaust valve closes, the intake valve opens and the cycle begins again. The four-stroke engine has four-strokes per cycle, one which produces usable energy. Each cycle takes two crankshaft revolutions, so the four-stroke engine produces one power stroke per cylinder for each two crankshaft revolutions.

Where the four-stroke engine uses valves to control the flow of fuel/air mixture and exhaust gas in and out of the cylinder, the two-stroke engine performs analogous functions by using the piston itself to cover and uncover holes or ports in the cylinder wall. Figure 2 illustrates the basic configuration of the two-stroke engine. Going left to right from top left, the first panel shows the piston traveling upwards in the cylinder, compressing the mixture above it, but just as importantly it is creating a low pressure condition in the crankcase area below the piston. As the piston reaches the top of its travel, in the second panel, the mixture above the piston is ignited and begins to burn and push down on the top of the piston. At the same time it can be noted that the bottom edge of the piston (the skirt) has uncovered the lower of the two ports shown on the right side of the cylinder. This port is the intake port and is fed by the carburetor. The opening of the intake port allows the low pressure condition in the crankcase area to draw the fuel/air mixture into this region below the piston. In the third panel the combustion force is still pushing the piston down; the piston skirt has re-covered the intake port, stopping flow into the crankcase and at the same time capturing the fuel/air mix which is already in this cavity. In the fourth panel at upper right the piston continues its downward motion, compressing the mixture which is trapped in the crankcase area below the piston. In the next panel, at bottom left, the top of the downward moving piston has now uncovered the upper port on the right side of the cylinder. This is the exhaust port and through it the rapidly expanding combustion products are allowed to escape from the cylinder.

In the next panel the piston has reached the bottom of its stroke and has fully uncovered the exhaust port. It has also uncovered the port on the left side of the cylinder which is called the transfer port. This port serves to "transfer" the fuel/air change which has been compressed below the piston to the combustion chamber above the piston. As shown in this panel, both the transfer and exhaust ports are uncovered at this time and as the next panel shows, the exhaust port remains open slightly after the piston, beginning its journey back up the cylinder, has closed the transfer port. During the period when both exhaust and transfer ports are open, the fresh charge coming up through the transfer port is mingling with the combustion products. The degree of mixing that does occur is influenced by subtleties in the shape and location of the transfer ports, but some mixing does occur, resulting in some exhaust contamination of the incoming charge and some escape of the raw incoming mixture out the exhaust port. This escape of fresh mixture out the exhaust port is called short circuiting and continues until the upward moving piston blocks the exhaust port completely as shown in the final panel.

There are two major characteristics of the two-stroke engine which make it an excellent choice for motorcycles. The first is its extreme simplicity, which also results in its compact size, light weight and low cost. A two-stroke engine has only a fraction of the moving parts, or total parts for that matter, of a comparable four-stroke engine. The second is that a two-stroke provides a power stroke for every revolution of the crankshaft, twice as many as a four-stroke. This generally allows a two-stroke engine to produce more output per displacement than a four-stroke. Figure 3 illustrates this difference: the two-stroke has a significant advantage throughout most of its operating range.

The advantages enjoyed by the two-stroke engine were enough to make it extremely popular for motorcycles. However, when it became necessary to meet exhaust emission limits, particularly for hydrocarbon, the two-stroke was at a severe disadvantage. The short circuiting phenomenon allowed relatively large amounts of raw, unburned fuel to enter the atmosphere. Some of the larger multi-cylinder two-stroke models from the early 1970's had HC emissions exceeding 25 grams per kilometer. While most models were not so extreme, it would unquestionably be difficult to get larger two-stroke models to meet HC emission standards. One manufacturer did considerable development on a direct cylinder fuel injection two-stroke, another developed a variable exhaust port device, but neither were able to make the two-stroke clean enough.

Most major manufacturers that had significant investment in two-stroke models investigated ways to meet the standards with them. However, when their research indicated that the type of modifications necessary would remove the two-stroke's simplicity, cost and performance advantages over the four-stroke, attention turned quickly to the latter engine type. At the time the EPA and California regulations were adopted, the accelerated demise of the two-stroke was well anticipated. It was popular (among regulators, anyway) to speak of "converting" two-stroke engines to four-stroke. This is a misnomer for there are virtually no common parts between comparable two-stroke and four-stroke designs. What manufacturers had to do was begin with a clean sheet of paper and design whole new engines, four-strokes, for their motorcycles.

It would be nice to claim that the designers, starting fresh, were able to discover the "pollution free secret" and thus churn out designs which met all future emission standards. Unfortunately, this was not the case. However, most of the initial new designs were able to meet the earliest emission standards with carburetor air/fuel ratio modifications and ignition timing adjustments. This resulted in many motorcycles that seemed to take forever to warm up, and more than a few customer complaints of lean surge and stumbling. Just about the time these models hit the market, EPA and California lowered their standards to 5 grams per kilometer HC and 12 grams per kilometer CO. California also adopted future HC standards which, in the finest emission standard tradition, have been modified on occasion but presently stand at 1 gram for small motorcycles (up to 280cc) and 2.5 grams for motorcycles over 280cc. No NOx standards have been set for motorcycles as their NOx levels are inherently quite low (at least at the present level of HC and CO control).

Current Control Techniques

The present control methods fall into some predictable categories such as ignition and fuel system optimization, with some slightly more innovative intake and exhaust modifications.

Ignition systems have received some attention, although the changes have more to do with prevention of deterioration than actual emission reductions. Breakerless and high-energy ignition systems are now almost universal, replacing the traditional breaker points. Some vacuum control of spark advance is being employed in motorcycles, as well as some electronic advance shaping. Centrifugal advance methods remain most prevalent.

Carburetion is an obvious emission control consideration, with a near universal abandonment of the traditional motorcycle slide-valve carburetor in favor of the constant velocity or constant vacuum (CV) design. The advantages of the slide-valve carburetor are its simplicity, its favorable flow characteristics, and its accurate, linear response to the rider's commands. Unfortunately, it supplies fuel in response to the rider's commands more than the needs of the engine. With the CV designs commonly in use now, engine intake is regulated by a butterfly valve which is operated by the throttle, and a piston valve which is controlled by a diaphragm that is sensitive to intake vacuum. Thus the engine is more likely to receive the correct mixture in spite of the throttle twisting habits of the rider.

Along with CV carburetor designs have come leaner settings and non-replacable jets which have not been too popular with the tinkerer types. Some manufacturers have also included a form of accelerator pump on recent designs to help get rid of a lean stumble which could make the motorcycle quite difficult to ride smoothly.

It is of interest that motorcycles are virtually all equipped with a separate carburetor for every cylinder. A couple of recent models use multiple venturi carburetors, with a venturi for each cylinder, but the automotive practice of a single carburetor feeding multiple cylinders through a manifold has never been applied to motorcycles.

One automotive feature which has just recently migrated across to motorcycles is electronic fuel injection. Due to its obvious complexity and cost, fuel injection has only appeared on a couple of high priced, state-of-the-motorcycle-art type of vehicles. To date, fuel injection has not been employed as strictly an emission control device; some consider it more a performance oriented feature with some marketing flair thrown in. Motorcyclists have exhibited some degree of black-box phobia towards any device they feel cannot be repaired by the roadside using a rock and a sharp stick. However the existing systems seem to be working quite well and cost is going to be a bigger factor in the spread of fuel injection than customer resistance.

Another type of intake system modification is aimed more at recovering driveability from emissions controlled lean carburetion. One manufacturer has cast a series of small passageways connecting the intake ports of a four cylinder engine. These passages, which open into the port very near the valve, use the momentum of the incoming charge to divert a portion of the charge from cylinder A, when its intake valve closes, to cylinder B whose valve in cpening. The charge traveling through the passageway has a relatively high velocity, and introduces additional turbulence into the mixture flowing into cylinder B. The manufacturer claims that this improves throttle response allowing the use of leaner mixtures.

Working at the problem from the other direction is a system to draw air into the exhaust port in the manner of the automotive air pump, but without the pump. This system illustrated at Figure 4, uses a negative pressure pulse which occurs in the exhaust pipe to draw fresh air into the exhaust stream through a one-way reed valve. The fresh air reacts with the exhaust gas to reduce the CO content. A vacuum operated switch valve stops the flow of air during deceleration to prevent backfiring. This system is well adapted to motorcycle use, as motorcycles generally have a single exhaust pipe per cylinder for a considerable distance compared to the typical automobile where exhaust goes into a collector manifold immediately after leaving the head. The long exhaust pipe allows for a more distinct low pressure pulse to activate the reed valve. This system works best when the carburetion is a little bit rich, thus ensuring a slightly rich exhaust to provide plenty of fuel for reacting with the fresh oxygen. Richer carburetion, in turn, gives good driveability, and that keeps the rider satisfied. Since no external air pump is required, and since there is no apparent performance reduction or weight increase, the more negative connotations of emission control are avoided.

Future Control Considerations

Manufacturers are facing one more control level; California's HC standard is scheduled to drop to 1 gram per kilometer for all large motorcycles in 1984, the same time that evaporative regulations will be applied for the first time to these vehicles.

Most motorcycles up to about 400cc are presently capable of meeting the 1 gram standard without evaporative controls, and with minor recalibration should still be able to meet it after evaporative countermeasures are applied. It is the larger motorcycles which present the greatest difficulties.

Catalyst technology, which has been researched by most manufacturers for several years, does not lend itself to motorcycle applications as well as it has for automobiles. A major concern is the temperatures of the catalyst and the housing, and how to adequately shield the rider and passenger when the motorcycle exhaust is so prominently exposed. Also, as mentioned earlier, the motorcyclist is highly inclined to simply remove or replace components that he doesn't like. Given the attitude of much of the public towards catalysts (as demonstrated by the volume business in "catalytic converter test pipes" done in muffler shops) it is assumed that motorcycle catalytic converters would repose by the thousands in garage corners across the land.

Similarly, air injection, thermal reactors, exhaust gas recirculation and other automotive control strategies, to the extent that they affect appearance, styling, weight or performance, are expected to be met by significant buyer resistance.

More widespread use of techniques to give driveability with lean mixtures, or reduce emissions by introducing oxygen to the exhaust products seems likely for the future.

The problem facing manufacturers for the future is no different than before, seeking to accomplish emission reduction goals without sacrificing the unique features and characteristics that make people buy and ride motorcycles.

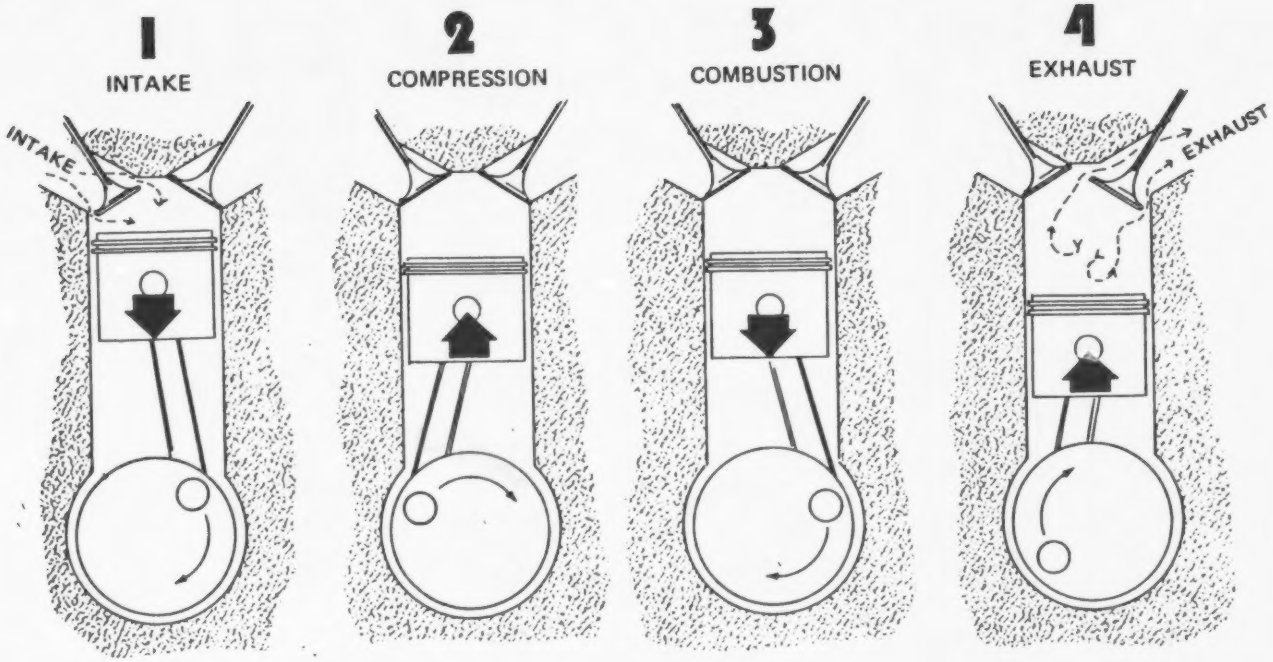

1
INTAKE
INTAKE
2
COMPRESSION
3
COMBUSTION
4
EXHAUST
EXHAUST

FIGURE 1

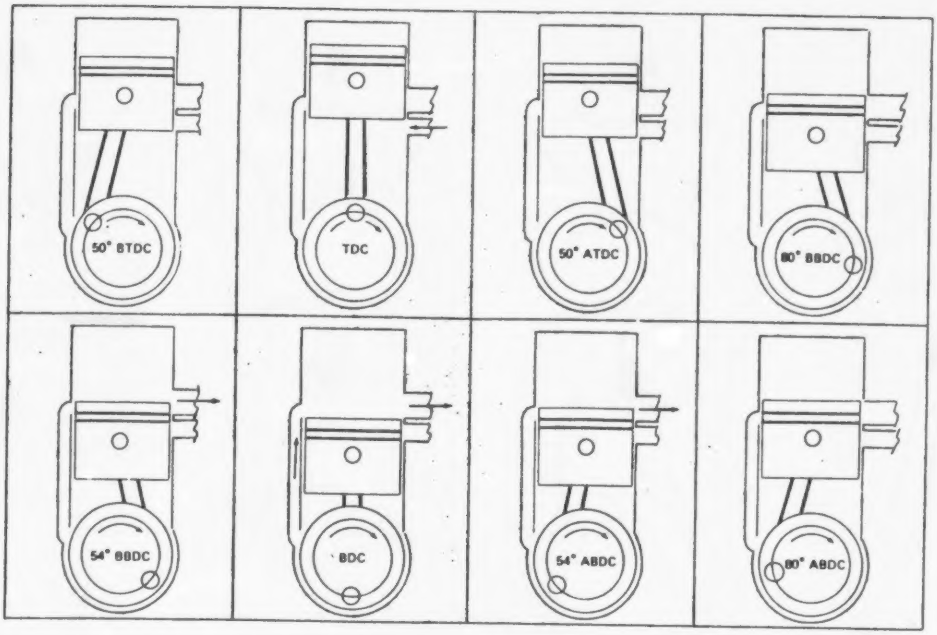

50° BTDC
TDC
50° ATDC
80° BBDC
54° BBDC
BDC
54° ABDC
80° ABDC

FIGURE 2

COMPARATIVE SPECIFIC OUTPUTS

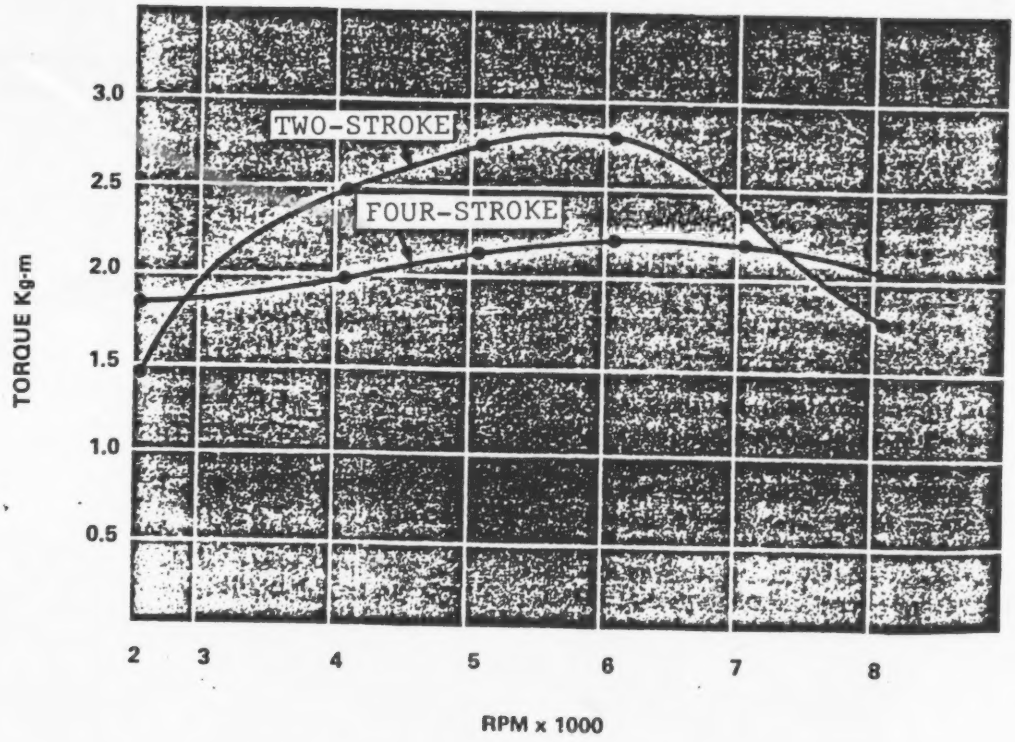


FIGURE 3

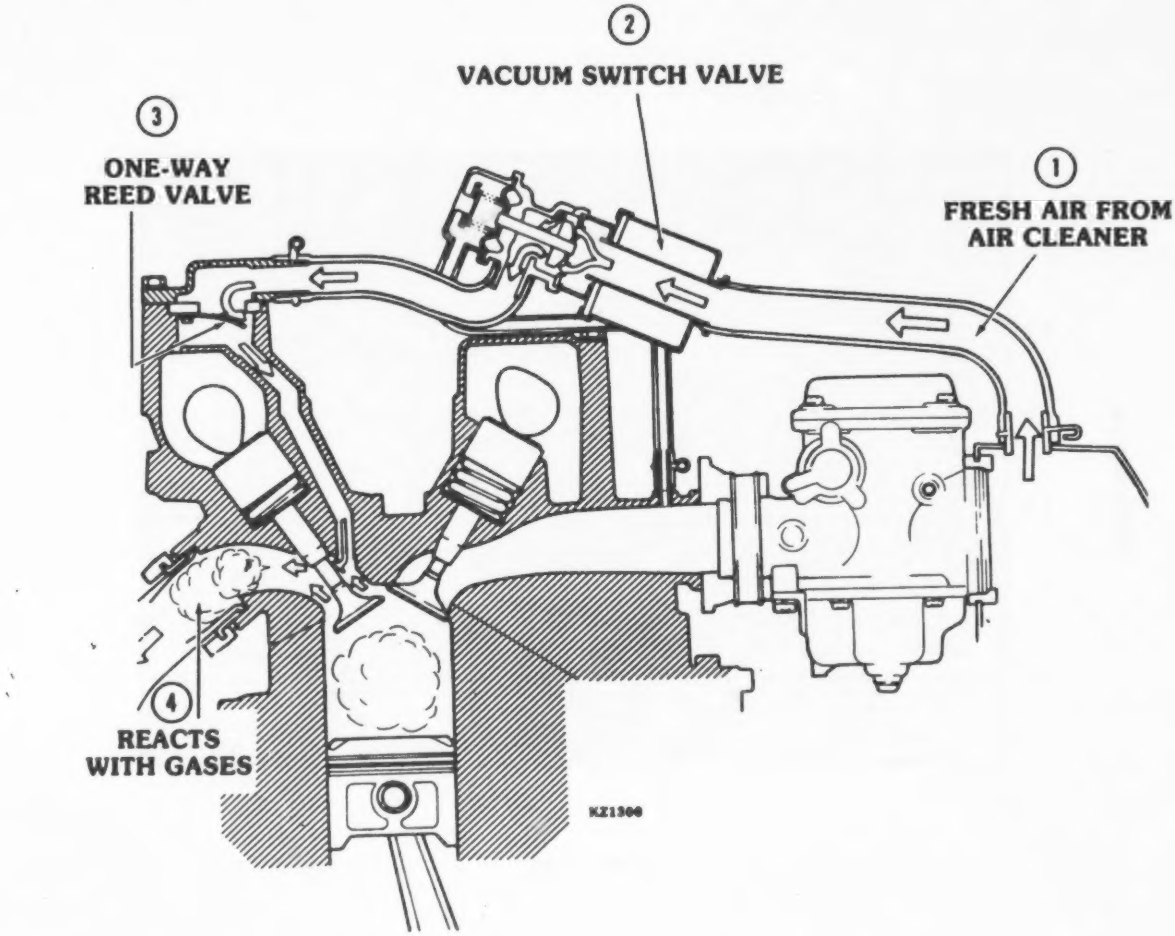

② VACUUM SWITCH VALVE
③ ONE-WAY REED VALVE
① FRESH AIR FROM AIR CLEANER
④ REACTS WITH GASES
KZ1300

FIGURE 4

CONTROL OF AIR POLLUTION BY USE OF ALTERNATE FUELS

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STAPPA
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ABSTRACT

Oxygenated fuels have been proposed for motor vehicles to reduce our dependence on foreign oil and reduce air pollution. This paper reviews the technical advantages and disadvantages. Pure methyl alcohol and ethyl alcohol can produce better mpg than gasoline with less emissions of CO and hydrocarbons in engines designed for these fuels. This would include fuel heaters, warm-up devices and high compression ratios.

These two alcohols can be used as blends with gasoline but present some problem if not kept dry. These blends have the possibility of greatly reducing CO emissions from older cars (pre 1975) and can be tailored to greatly reduce emission resulting from enrichment due to high altitude and high temperature. These blends give about 2% less mpg and may present cold starting problems in existing cars.

INTRODUCTION

There has been a lot of talk about using alcohols as fuels or fuel supplements to reduce the dependence on foreign oil and as a means to reduce air pollution. There have been many technical studies published on the production of alcohols, and alcohols as fuels. Some have been poorly planned and add to the confusion, but some have been well done. We hope this review can help you understand what effect fuels containing alcohols and other oxygenated organics, could have on air pollution in your area.

PROPERTIES OF OXYGENATED FUELS

To begin, let's look at the composition and properties of Gasohol, alcohols and other oxygenated organics that are being considered as fuels for internal combustion engines. These are shown in Table I. Several of these properties result in advantages or disadvantages for oxygenated fuels. The higher initial boiling points compared to gasoline result in cold starting problems with existing cars. The high heat of evaporation also contributes to this and to poor distribution of fuel, but these problems can be overcome. The lower heat of combustion of oxygenated organics means less miles per gallon in existing cars, but the high octane numbers mean that new cars could be designed with higher compression ratios and get more power. The lower stoichiometric ratios of oxygenated fuels will lean out existing engines, thus older cars that were designed rich will have lower hydrocarbon and CO emissions. Cars that are near the lean limit may have increased hydrocarbon emissions due to lean misfires. High altitudes enrich nearly all cars and cause greatly increased emissions. Alcohol-gasoline blends can compensate for this and bring emissions back to design. So we see that the difference in properties can have a big influence on combustion, performance, emissions and fuel economy.

TABLE I

PROPERTIES OF GASOLINE AND OXYGENATED FUELS

FUEL	FORMULA	B.P. °F	SP. GR.	HEAT OF EVAP. BTU/GAL	HEAT OF COMB. BTU/GAL	STOICH. RATIO	EXPLOSIVE LIMITS		AUTO. IGN. TEMP.	OCTANE NO.	
							LOWER	UPPER		RES.	MOTOR
Gasoline	Avg C_8H_{15}[1]	100-400	0.75	980	114,000	14.6:1	1.3	6	495	92	83
Methyl Alcohol	CH_3OH	147	0.79	3300	56,100	6.4:1	6	36.5	878	110	91
Ethyl Alcohol	C_2H_5OH	173	0.79	2600	76,900	9.0:1	3.3	19	799	111	92
Gasohol	10% C_2H_5OH 90% GASOLINE	100-400	0.76	1130	110,300	14.0:1	---	----	---	96[+]	85[+]
Tertiary Butyl Alcohol	$C_4H_{10}O$	180	0.78	1700	93,000	11.0:1	(1.4)[2]	(11.2)[2]	901	---	--
Methyl Tertiary Butyl Ether	$C_5H_{12}O$	138	0.72	920	93,300	11.7:1	(1.9)[3]	(24.0)[3]	---	---	--

[1] Gasoline is composed of hundreds of hydrocarbons mostly containing 5 to 10 carbon atoms/molecule

[2] Values for n-butyl alcohol

[3] Values for ethyl propyl alcohol

[+] A synergistic effect always occurs

COMBUSTION OF PURE GASOLINE OR OXYGENATES

Ideal Combustion of Gasoline

First let's look at ideal combustion in the internal combustion engine before we show specific data. First we make a stoichiometric mixture of air and fuel by means of a carburetor, or by fuel injection. It is intended that this be a completely homogeneous vapor mixture. This mixture is then distributed to the combustion chambers. At an optimum time, the mixture is ignited by a spark and the flame burns through the entire mixture until it is about five hundredths of an inch from the cylinder wall. At this point, heat loss to the wall puts the flame out. There is a thermodynamic tendency for the combustion products to be small stable molecules, like CO_2 and water. The resulting CO_2 and water and small amounts of unburned fuel from the mixture next to the wall, pass to the exhaust system.

Emission Formation

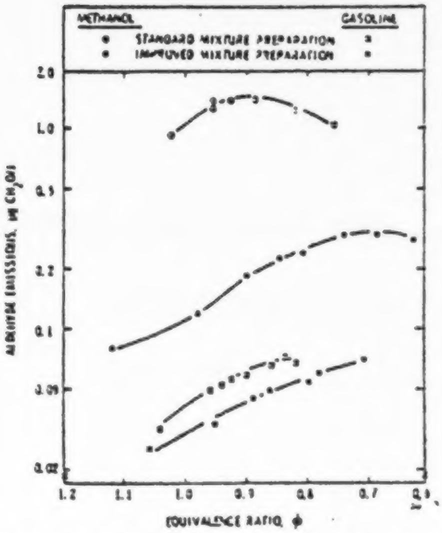
If any part of the mixture has excess fuel (rich) then some CO and H_2 will be formed in the combustion. If the mixture is too rich or too lean, or the spark timing is not right, additional fuel will remain unburned or be partly decomposed to a wide variety of smaller olefins, hydrocarbons and oxygenates. A little of this CO and fuel may burn in the exhaust system. Some nitrogen and oxygen from the air react to form nitric oxide, NO. High temperatures and excess oxygen promote this reaction.

Combustion of Alcohols

The most stable products of combustion of alcohols are CO_2 and water, as with all organics. If insufficient oxygen is present some CO and hydrogen will result. Wall quenching also leads to emissions of unburned fuel and intermediate products such as aldehydes.

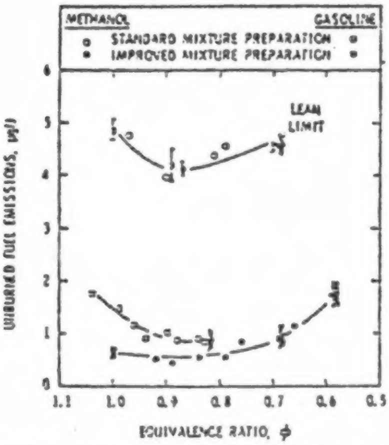
Let's consider the burning of pure methyl alcohol under ideal conditions. Because of the high heat of evaporation (three times that of gasoline) and higher initial boiling point, the fuel must be heated to get a homogeneous mixture.[1] However, the high octane number of methanol and leaner misfire limit permit the engine to be operated lean up to 16:1 compression ratio (CR), but 12:1 was found to be optimum. The equivalence ratio was 0.89 (lean). This produced a thermal efficiency of 40%, compared to 27% for gasoline at a compression ratio of 8.2:1.[2] Formaldehyde emissions were 3 to 4 times as much as for gasoline (Figure 1)[1] but were still quite low. Because of the lean operation, CO emissions were very low. Figure 2[4] shows that unburned fuel emissions were about the same as for gasoline, but the emissions were essentially all methanol. If an ordinary intake system were used fuel emissions are higher and so are aldehydes. The photochemical reactivity of methanol is low compared to emissions from gasoline[3], but formaldehyde has a high reactivity. Since formaldehyde is a relatively minor constituent the overall reactivity is lower with methanol than with gasoline as shown in Table II.[4] Methanol can be made from coal, wood or other organic material and thus eliminate our dependence on foreign oil. A vehicle built for methanol could give better fuel economy and lower emissions than current cars. Cold starting would be a problem, but otherwise good performance would result. Methanol produces no particulates.[2]

Pure ethyl alcohol has most of the same problems and advantages as methanol. However, it is primarily made from agricultural products, not coal. It also has a high heat of evaporation and needs a car designed to supply more heat to the fuel. It has a high octane and can be operated lean at high



Mixture preparation effects on aldehyde exhaust emissions with methanol and gasoline fuels

Figure 1 Reference 1



Mixture preparation effects on UBF exhaust emissions with methanol and gasoline fuels

Figure 2 Reference 1

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TABLE II

TOTAL EXHAUST HYDROCARBON REACTIVITY

		Total Reactivity		
	Car	Base	15% MeOH	Change Due to MeOH
Matched RVP	1967	2.95	2.29	-0.66
	1973	0.64	0.61	-0.03
	Catalyst	0.03	0.04	+0.01
Non-Matched RVP	1967	2.50	2.17	-0.33
	1973	0.66	0.90	+0.24
	Catalyst	0.04	0.12	+0.08

Reference 3

compression ratios to give increased mileage compared to gasoline. Brazil[5] has made extensive tests on cars using 96% ethyl alcohol. The CR was increased from 7.2:1 to 11:1 resulting in a 4% increase in fuel economy in normal use and 18% increase in maximum power. Intake temperatures must be kept below 290°C to prevent thermal decomposition of the alcohol with resulting engine damage.

The other oxygenated fuels, tertiary-butyl alcohol and methyl tertiary-butyl ether, would present fewer problems in evaporation, but they are primarily petroleum derivatives. Few studies have been done on them. All of these compounds have higher vapor pressures and increased evaporative emissions compared to gasoline. Refinery blending could minimize this problem.

A few years ago there was a big push by the government to produce more alcohol for fuel, but this has largely subsided. Pure alcohol fuels and engines designed for them would not appear to be available in quantity in the 80's.

ALCOHOL-GASOLINE BLENDS

All of the compounds listed in Table I can be blended with gasoline to make hybrid fuels. However, one of the biggest problems with alcohol-containing fuels is phase separation in the presence of water. If this occurs, water and alcohol are one phase, and it settles to the bottom. Alcohol-water *or* gasoline may then be delivered to a car instead of the desired blend. This separation also accelerates tank corrosion. If the water layer is discarded to prevent corrosion, then expensive alcohol is also lost. Gasoline plus 10% methanol can tolerate only about 0.1% of water at 60°F[6] and the problem is worse at lower temperatures. Because of this, methanol blends are not being marketed, even though methanol is currently available in larger quantities and is only about one-half the cost of ethanol. Gasoline plus 10% ethanol is a little more tolerant of water.

GASOHOL

Gasohol, defined as 10% dry ethanol in gasoline, has been marketed widely, thus proving that the water problem can be handled on a commercial basis. In 1981 the price of fermentation anhydrous ethanol ranged from $1.70 to $2.00/gallon.[7] On a comparable basis (tank truck quantity) unleaded gasoline was about $1.10/gallon making gasohol about $1.18/gallon, but it has a higher octane. This is estimated to be worth about 2¢/gallon,[8] therefore, the refiner could produce a cheaper gasoline for blending to gasohol and still have a product comparable to gasoline at about $1.16/gallon. In 1979 Gasohol consumption was about 52,000 barrels/day, only about 0.7% of gasoline consumption.[9]

Control Systems

We want to determine the effect of Gasohol use on existing cars so let's look at the control systems on the road. The common emission control systems are listed in Table III. Previous to 1968, U.S. engines were designed to have a compression ratio of about 9.5:1 and to use a mixture containing excess fuel to produce maximum power. The fuel was leaded gasoline with an octane number around 95. From 1968 to 1972 the mixture was leaned, to lower hydrocarbon and CO emissions. In 1973 and 1974 exhaust gas was recycled to the engine which put these engines near the lean limit. Performance was borderline. From 1975 to 1982 most cars had oxidation catalyst control systems. This required enriching the mixture to produce more emissions in the engine to keep the catalyst hot enough for high conversion. This also resulted in better performance. The compression ratio was about 8.5:1, and 90 octane no-lead gasoline was required. The stratified charge engine controls emissions in the engine. It has a small chamber where a rich mixture is ignited. The

TABLE III

AUTOMOBILE EMISSION CONTROL SYSTEMS

YEARS	EMISSIONS, G/Mi			MIXTURE	FEATURES
	HC	CO	NOx		
Before 1968	9	90	4	Rich 13:1	Prior To Control
1968 - 1971	6	40	8	14:1	Leaner, Some Exh. Air
1973 - 1974	3	28	3	14.2:1	EGR
1975 - 1981	1.5	15	2	Richer 13.5:1	Catalyst, No Lead, CR 8.
1983 +	0.4	3.4	1	Exactly Stoich. 14.6:1	3-Way Cat., Exh. Anal.
1973 - 1974	3	28	3	Very Lean 18:1	Lean Burn
1972 - Pres.	1.5	15	3	Rich / Lean 14.5:1 20.5:1	Stratified Charge

burning gases flow into a very lean mixture and ignite it. The leanness of this mixture reduced CO emissions and wall quenching. The other control system we should consider is just reaching the market. It is a 3-way catalyst system. One catalyst controls HC, CO and NO, but to do so, it must have a mixture of fuel and air very close to the stoichiometric ratio. This is accomplished by analyzing the exhaust, and feeding this and other operating data to a small computer that calculates the exact fuel needed. This information is used to control the fuel rate.

Combustion of Gasoline-Alcohol Blends

Since Gasohol is already available in limited quantities, and the amount could be increased without much difficulty, let's consider its use in existing cars without adjustment and at ordinary temperatures and altitudes. Since the stoichiometric ratio is changed from 14.6 to 14.0 the mixture entering the engine will average 4% leaner in most cases. Because of the higher heat of evaporation of ethanol more fuel remains as droplets and this leads to a greater variation in equivalence ratio than when gasoline is used. Because of intake valve design, these alcohol droplets tend to be thrown to the cylinder walls where they wash away lubricant and increase corrosion. The increased concentration of fuel at the wall increases unburned fuel in the quench zone and counterbalances the decrease normally expected from a leaner mixture.

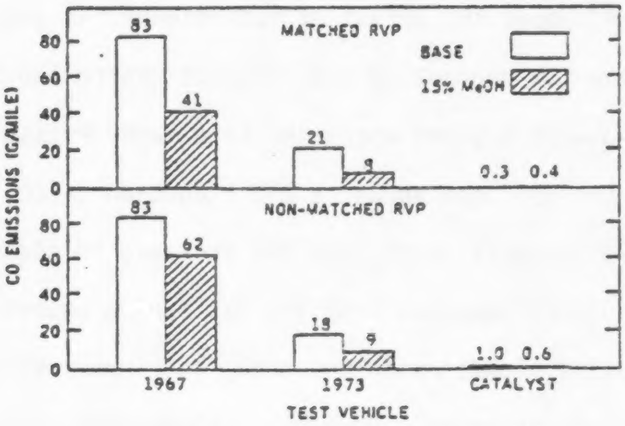
Lower CO emissions do result from the leaner mixture. The leaner mixture would be expected to increase NO_x but the lower heat of combustion decreases the peak temperature enough to counterbalance this. This lower heat of combustion makes fuel economy about 2% lower with Gasohol.

Effect of Blends on Control Systems

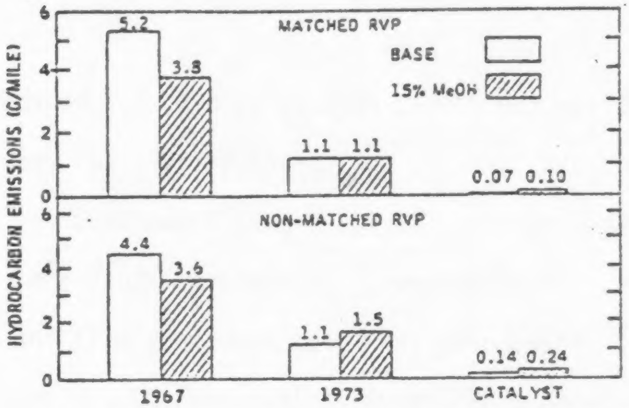
Figure 3 and 4[3] shows the effect of 15% methanol in gasoline on uncontrolled (1967), lean-EGR controlled and catalyst controlled (1975) cars. Each car was also tested with a blend where the Reid Vapor Pressure was matched. With matched RVP, the 1967 car showed a 51% reduction in CO, 27% reduction in hydrocarbons, a 27% increase in NO_x and 54% increase in aldehydes. This is just about what would be expected from the 5% leaning caused by the alcohol. With ordinary gasoline blended with methanol, the improvements were in the same direction but not as great. Warm-up problems were responsible for this loss of improvement. This is more like present Gasohol would be expected to give.

With the 1973 car the CO was reduced by 62%, hydrocarbons were unchanged and NO_x was reduced 35%. Again, the unmatched RVP fuel was not quite as good. Figure 5[10] shows the results with 10% methanol and Gasohol (10% ethanol) on 1973 and 1974 cars. In this case CO was reduced about 50%, hydrocarbons about 3% and NO_x 10-20%. These data show good agreement with the previous data. Although leaning a rich engine usually increases NO_x, a lean engine such as this may be expected to reduce NO_x, partly because the lower heat of combustion reduces the peak temperature which contributes to NO_x reduction.

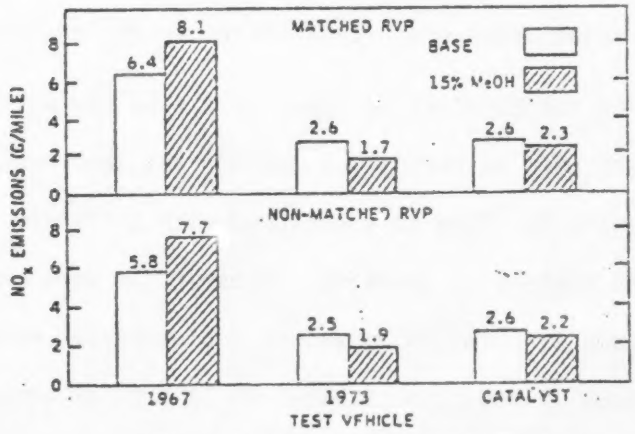
In the case of the catalyst equipped 1975 type car with 15% methanol fuel, CO and hydrocarbons were extremely low and NO_x was lowered slightly.[3] Table IV[11] shows similar results for five cars equipped with oxidation catalysts with various oxygenated fuels plus gasoline. These fuels were not adjusted for RVP and showed increased evaporative emissions and decreased miles per gallon. The catalyst system usually has rich carburetion to provide enough emissions to burn on the catalyst and keep it up to an efficient operating temperature.



Effect of methanol on 1975 FTP CO emissions

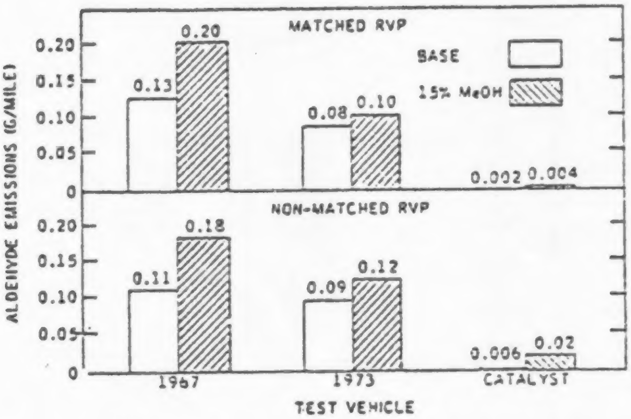


Effect of methanol on 1975 FTP hydrocarbon emissions



Effect of methanol on 1975 FTP NO_x emissions

Figure 3 Reference 3



Effect of methanol on 1975 FTP aldehyde emissions

Figure 4 Reference 3

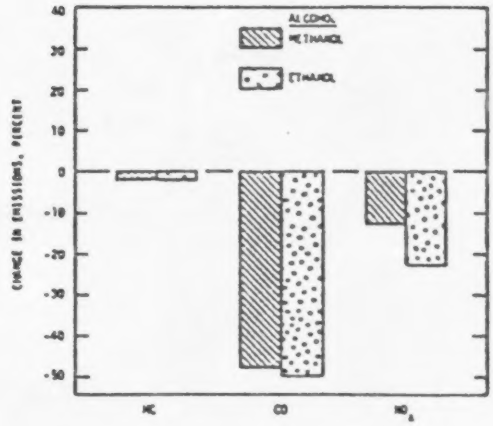


Fig. 1 Change in emissions caused by adding 10 percent alcohol to gasoline P, 1975 FTP, car X with production carburetor

Figure 5

Reference 10

Summary of the Exhaust Emissions, Evaporative Emissions, and Fuel Economy

Fuel Description	Fuel Economy, mpg Urban	Emissions, gm/mile HC	CO	NOx	Aldehydes mg/mile	Total Evaporative Emissions, gm
	OXIDATION CATALYST VEHICLES (5-CAR AVERAGE)					
Fuel No. 1 (Indolene)	18.6	0.85	8.56	1.63	18	2.8
Fuel No. 2 (Indolene + 10% ethanol)	17.9	.58	4.66	1.63	18	4.0
Fuel No. 3 (Indolene + 10% methanol)	17.5	.62	4.64	1.89	27	5.4
Fuel No. 4 (Indolene + 7% MTBE)	18.0	.68	5.78	1.62	14	3.5
Fuel No. 5 (Indolene + 7% TBA)	18.0	.78	7.88	1.75	17	3.0
	3-WAY CATALYST VEHICLES (3-CAR AVERAGE)					
Fuel No. 1 (Indolene)	18.5	.43	6.23	0.48	4	2.0
Fuel No. 2 (Indolene + 10% ethanol)	18.0	.39	4.55	.59	8	2.3
Fuel No. 3 (Indolene + 10% methanol)	17.1	.41	4.47	.71	4	3.8
Fuel No. 4 (Indolene + 7% MTBE)	17.9	.31	4.51	.65	7	2.2
Fuel No. 5 (Indolene + 7% TBA)	17.7	.32	4.89	.58	9	2.1

Table IV

Reference 11

Too much leaning could cause a decrease in catalyst efficiency and increased emissions. Table IV does not show such an effect. The maximum leaning used was about 5.5% with 10% methanol. This could show up as the catalyst loses activity with age.

Table IV also shows similar results with a 3-way catalyst and closed loop fuel system. This would be expected to compensate for fuel changes, and automatically adjust to the desired equivalence ratio of 1.0, and have emissions identical to those with gasoline. Since CO was a little lower and NO_x a little higher it would appear that the carburetion was a little leaner with these fuels.

At this point we should put in a word of caution about comparing percentage reductions as we have done. Going back to CO emissions on Figure 3, the reductions on the 1967 car were 51%, the 1973 car were 62% and the catalyst car an increase of 33%, yet the actual decreases were 42 g/mile, 13 g/mile and -0.1 g/mile. Thus, switching one 1967 car to this fuel would do as much good as 3.4 1973 cars or it would counterbalance the increase caused by 420 catalyst cars.

No data was found for cars with 1968-72 emission controls. However, they were mostly similar to pre-1968 engines except not quite so rich. They were not near enough to the lean limit to cause problems when leaned 4 or 5% with Gasohol, therefore it is expected that the emissions of CO and HC would be significantly reduced and NO_x and aldehydes would increase, but the changes would be smaller than for the 1967 cars shown in Figures 3, 4 and 5.

In the case of the Lean Burn engine, it is so lean that further leaning may put it beyond the combustible range and either greatly increase hydrocarbons, and reduce NO_x, or the engine may even fail to operate at all.

However, these are a very small percentage of the population. Stratified charge engines may also have a similar problem.

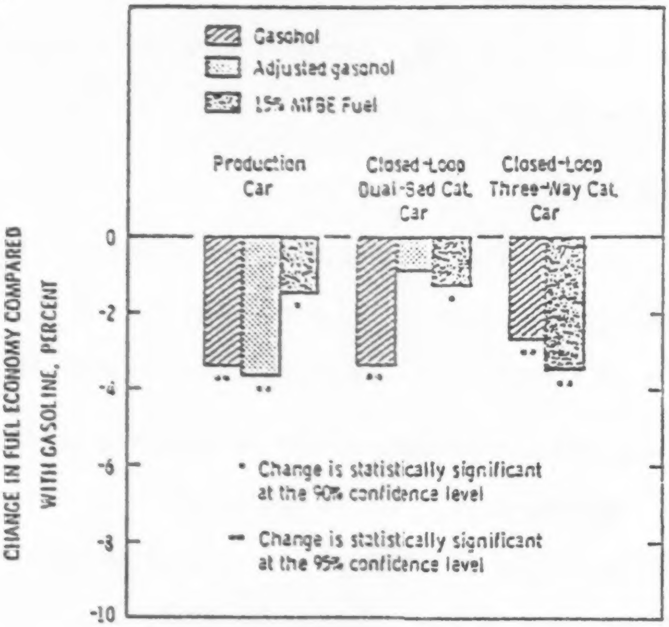
In summary, cars up through the 1974 model year that use Gasohol will probably have reduced CO emissions and some reduction of hydrocarbons. NO_x may be increased or decreased. These cars presently use regular leaded gasoline, too, so it would be advantageous from an air pollution viewpoint to switch this fuel to Gasohol. The 1975 to present catalyst cars would not be affected much by Gasohol and may lose their activity sooner. These presently use unleaded regular gasoline. Air pollution control would not be helped by replacing this with Gasohol.

Performance Effects With Gasohol

In addition to exhaust emission changes, the use of Gasohol is known to effect several other performance items. The most important of these are the volumetric fuel economy, the evaporative emissions, and driveability.

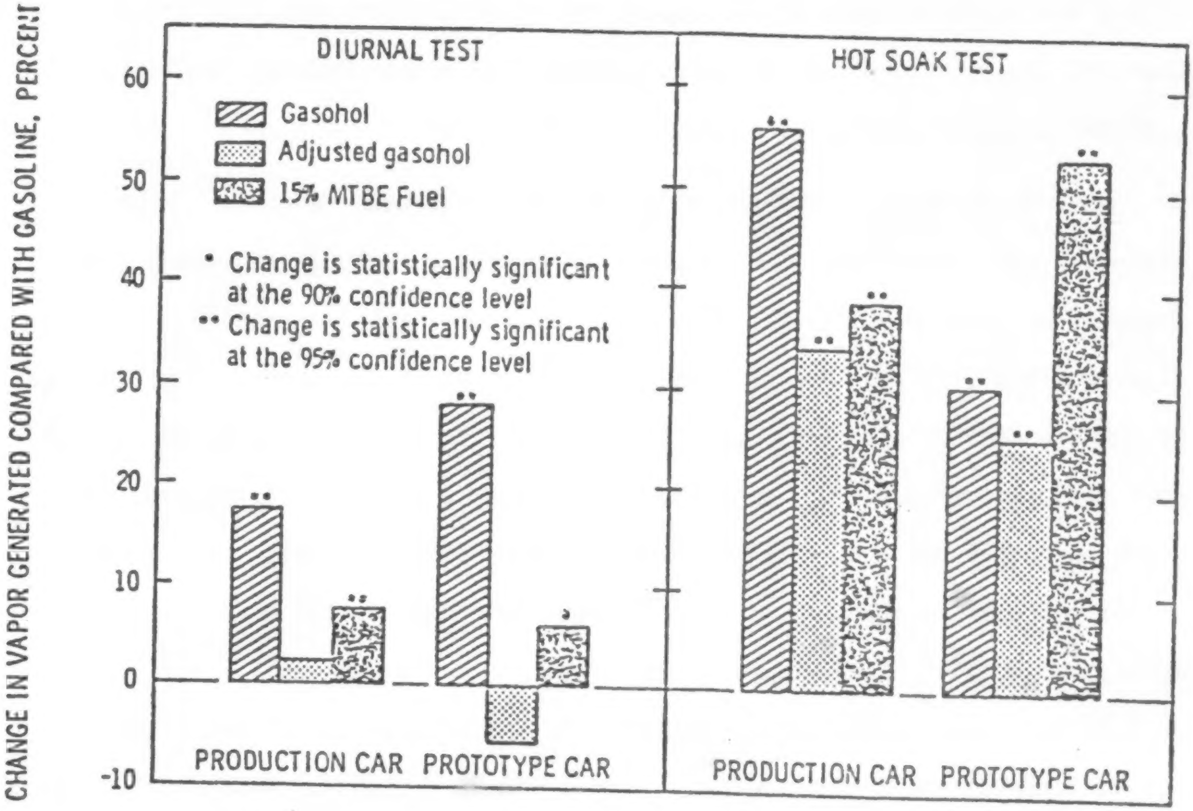
For in-use vehicles, the use of Gasohol may be expected to yield a decrease in volumetric fuel economy. This is due to the lower heat of combustion of the blended fuel. The addition of 10% ethanol to gasoline will generally yield a 3-4% decrease in fuel economy in catalyst-equipped vehicles, as shown in Figure 6.[12] A similar effect would be anticipated for other vehicles.

The effect on evaporative emissions when a vehicle is fueled with Gasohol has also been shown to be detrimental. The results of one study have shown an increase in evaporative emissions of up to 43% for vehicles equipped with vapor recovery systems. These increases are due to the rise in vapor pressure associated with the blended fuel. Another study[11] (Figure 7) shows that the



Effect of ethanol and MTBE on EPA city fuel economy

Figure 6 Reference 12



Effect of ethanol and MTBE on total vapor generated during evaporative emissions tests

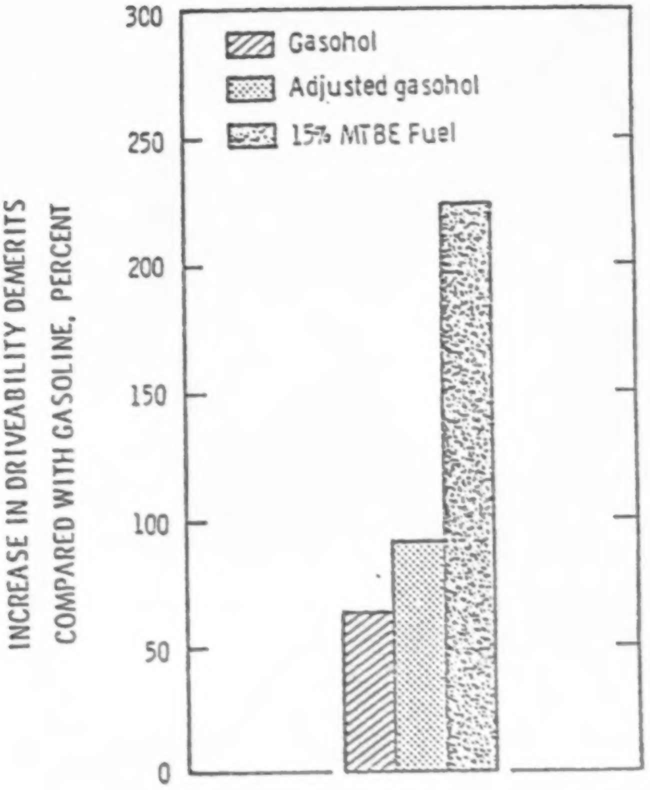
Figure 7

Reference 12

increase in vapor generation is much more pronounced during the hot soak test than during the diurnal test. While the diurnal test showed an increase of approximately 18%, the hot soak exhibited an increase in excess of 50%. This phenomena is the result of the manner in which the vapors are generated. During the diurnal test the primary source of vapor is the fuel tank, while during the hot soak, most of the vapors are generated from the carburetor. However, the overall effect on emissions was held within Federal regulations with the present evaporative emission control system.

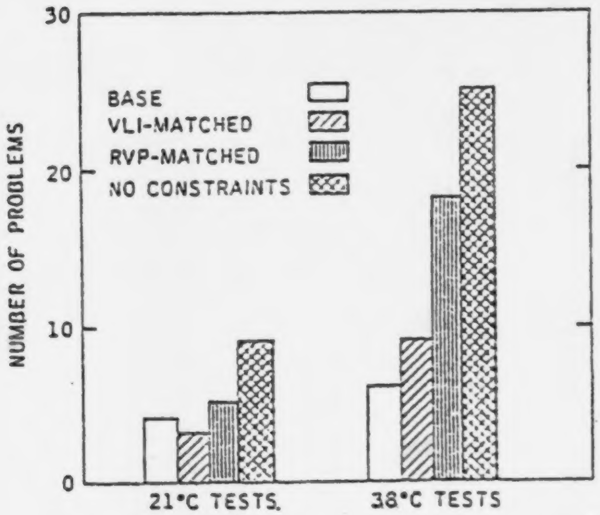
Another performance effect of Gasohol which has been reported[11] regards driveability. Specifically, cold-start driveability depicted in Figure 8 was found to be adversely effected by the use of alcohol gasoline blends. This is probably due to the leaning effect of the alcohol. The increased volatility of the blended fuel can also lead to an increase in vapor lock problems during high temperature operation. One study[3] has shown a significant increase in the number of vapor lock problems encountered by vehicles fueled with a blend of 15% methanol in gasoline. Figure 9 shows this detrimental effect was much more pronounced at higher temperatures compared to the base fuel. This problem was somewhat reduced by adjusting the vapor pressure of the blend. Similar effects could be anticipated with a standard blend of Gasohol although the problems should be less severe.

One other driveability effect associated with Gasohol is the aforementioned synergistic effect on octane. The increase in octane number shown in Table I provides much better anti-knock performance which is a definite benefit for some of the newer catalyst-equipped vehicles whose performance in this area on regular unleaded fuel is marginal.



Effect of ethanol and MTBE on
cold-start driveability of the production car

Figure 8 Reference 11



Number of vapor lock problems encountered as a function of fuel at two test temperatures

Figure 9 Reference 3

While most of the performance effects of Gasohol have been shown to be detrimental, all but the fuel economy penalty are thought to be such that they could be overcome by appropriate blending with an adjusted base fuel which would reduce the vapor pressure of the blend.

Potential Advantages Of Oxygenated Fuels

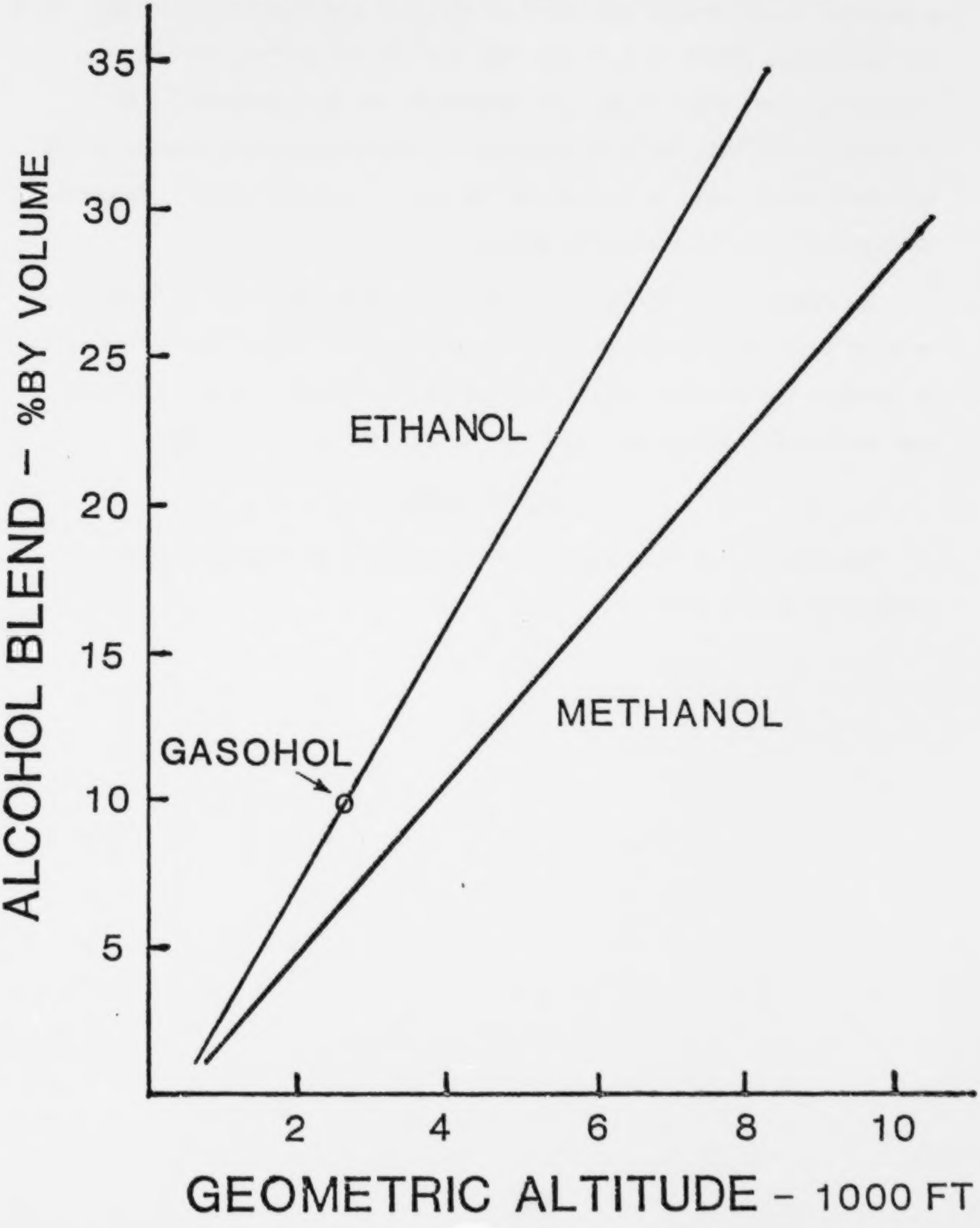
The chemical leaning of the fuel and air mixture provided by the addition of oxygenates to gasoline shows promise for improved emissions performance in the following specific cases: high altitude operation, high temperature operation, and operation of pre-1975 older vehicles. In each case these modes of operation are associated with an enriched mixture. In the first two cases the enrichment is due to a reduction in air density compared to the design point while, in the third case the vehicle was designed to operate in a rich mode.

Let's first consider the operation of a conventionally carbureted vehicle at an altitude greater than its design point. As altitude increases, the reduction in air pressure is accompanied by a reduction in air density. The fuel metering system is such that for any throttle position and manifold vacuum, a fixed volume rate of air is passed into the engine. At the same time, the fuel flow rate, which is governed by the velocity of air through the venturi, remains unchanged from its design point. Since the density of the air is reduced, the mass rate of air is also reduced, and the A/F ratio, which is determined on a mass basis, becomes enriched. The enrichment of the main-metering system has been shown[13] to be inversely proportional to the square root of the ratio of the actual air density to that at the design point. In most cases,except a closed-loop (3-way catalyst system),this enrichment will lead to an increase in emissions of carbon monoxide and hydrocarbons, and a decrease in the emission of oxides of nitrogen from the engine. The information which is available suggests that this variation in emissions is nearly linear with altitude. One study[14] has shown that the rates of change in emissions with altitude expressed as a percent change per 1000 ft. in elevation are 15% for CO, 7.7% for HC, and -6.2% for NO_x for a precatalyst era vehicle. Using Denver as an example, we could therefore anticipate a 79% increase in CO, a 40% increase in HC, and a 32% decrease in NO_x from a vehicle which was not modified for high altitude operation.

If we were to adjust the air-to-fuel ratio of a vehicle by chemical leaning of the fuel with oxygenates, we could effectively return the engine operating condition and its emission performance to the original design point, or lower. By using the density ratio to compute enrichment, we have developed a relationship which gives the volume percentage of alcohol required to compensate for this enrichment as a function of altitude. This is shown in Figure 10 for both ethanol and methanol. It may be seen that standard gasohol provides compensation at an altitude of 2700 feet. This analysis neglects the minor effect of the change in fuel density of the blend. Research is currently underway at the University of Cincinnati to experimentally verify this relationship under simulated altitude conditions.

While this discussion has been limited to non-catalyst-equipped vehicles, it is anticipated that oxidation catalyst vehicles would behave in a similar fashion. The enrichment provided by altitude operation would certainly increase the emission of CO and HC while the vehicle was operated after a cold start, prior to the achievement of operating temperature in the catalyst.

ALCOHOL BLEND VOLUMES REQUIRED AT ALTITUDE



The effect of an increase in ambient temperature above the design point is identical to an increase in altitude. Both conditions are accompanied by a decrease in air density and therefore enriched operation of the engine. While the temperature effect is much less than the altitude effect, the use of oxygenates in the blend could again compensate for this enrichment. An increase from 70°F to 100°F in operating air temperature would provide a 2.7% enrichment which could be overcome by the use of standard Gasohol. Temperature compensation could be seasonally adjusted.

The degree of improvement in CO and HC emissions which can be realized by older vehicles still in operation depends on their actual air-to-fuel ratio. In general, the chemical leaning provided by the blended fuel would usually tend to reduce CO and HC emissions but increase the emission of NO_x.

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ALCOHOL FUELS, THE CALIFORNIA PROGRAM

By Robert H. Cross

State of California
AIR RESOURCES BOARD
Mobile Source Control Division

April, 1982

ALCOHOL FUELS, THE CALIFORNIA PROGRAM

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Abstract

Passenger cars fueled with ethanol and methanol from three California Energy Commission fleets have been emission tested by the California Air Resources Board. The fleets include Ford Pintos, which have been retrofitted for alcohol fuels, and Volkswagens and Ford Escorts which were designed with manufacturer involvement to be mass producible in the near term. The emission tests results show that the alcohol fleet vehicles are capable of meeting California's stringent exhaust emission standards, provided the three-way catalyst emission control systems are retained. Further optimization could result in lean burn engines which would provide improved efficiency.

Introduction

It has long been known that methanol and ethanol can be used to fuel internal combustion engines. In engines which are optimized for maximum power these alcohols generally produce more power than gasoline, hence methanol is a common racing fuel. Alcohols have not become the motor vehicle fuel of choice primarily because, on an energy basis, they still cost more than traditional petroleum fuels. It is anticipated that dwindling petroleum supplies will ultimately result in higher gasoline and diesel prices which will cause alcohols to become cost competitive. Coal derived gasoline and alcohol have been determined to be cost competitive with each other by the Environmental Protection Agency (EPA).

The California Legislature has recognized the potential of alcohols for replacing petroleum in motor vehicles. In order to promote the use of alcohol fuels, it has allowed the use of 10% ethanol in gasoline for 3 years provided the gasoline has a Reid Vapor Pressure (RVP) of 9 pounds per square inch (PSI) or less. The RVP was limited because the addition of alcohol to gasoline increases the gasoline's volatility, hence evaporative emissions. The legislature has also exempted ethanol used as motor fuel from beverage taxes and established a 10 year experimental program which allows anyone to use alcohol fuels in motor vehicles.

Probably the most significant action by the California Legislature was the establishment in 1979 of an alcohol fuels program which was funded for 10 million dollars.[1] The California Energy Commission (CEC) is charged with administering funds for this program in order to (1) demonstrate the feasibility of ethanol production and (2) provide vehicle fleet demonstrations with pure alcohol fuels.

The ethanol production portion of the funds were allocated to a number of feasibility studies. One pilot ethanol plant, the "Raven Distillery" is operational when biomass is available. It is a converted winery which was partially funded with state money. The contractor will buy back the state's investment if agreed upon performance objectives are met. At the present time it is operating on a conditional permit pending resolution of an odor problem, and new equipment is being installed which will allow the facility to produce up to 8 million gallons per year of ethanol. Another project which the Energy commission considered for construction funding, the "Still Gas" operation, was determined not to be economically feasible.

The vehicle fleet demonstrations involve three fleets of passenger cars operating on pure ethanol or pure methanol. Alcohol Energy Systems in Santa Clara, California is the prime contractor for the first two fleets. The first fleet, "Fleet I", consists of eight 1980 Ford Pintos. Four were converted to burn ethanol and the other four burn methanol. Two cars on each fuel retain the standard compression ratio, while the other two use high compression pistons to improve thermal efficiency. The Pintos demonstrate the types of modifications which could be performed in the aftermarket to convert gasoline cars to alcohol fuels.

Fleet II consists of 37 1981 Volkswagens which were manufactured on the assembly line with the necessary modifications to burn alcohol. Eighteen are calibrated for methanol, and the other nineteen burn ethanol. The VW's have been assigned to various agencies for mileage accumulation and driveability evaluation. Two of them are assigned to the Air Resources Board's Haagen Smit Laboratory where they will be periodically emission tested as mileage is accumulated.

Fleet III consists of 40 Ford Escorts which will be used by Los Angeles County. All of them have been calibrated for methanol. The calibration and other modifications were developed by Ford Motor Company and final assembly including the installation of high compression pistons was performed by Bill Stroppe and Sons in Long Beach.

The California Air Resources Board (CARB) has cooperated with the CEC by performing emission tests on vehicles from the various fleets including measurement of the various hydrocarbon species to determine the exhaust composition from alcohol vehicles. In addition CARB has performed some additional experiments to evaluate the effectiveness of various emission controls on alcohol fueled cars. In this paper, the potential benefits associated with using alcohol fuels will be discussed from CARB's perspective, then the results of the CARB emissions tests will be presented. Finally, the most promising areas of current research will be discussed.

CHARACTERISTICS OF ALCOHOL FUELS/BENEFITS

Alcohols differ from petroleum motor fuels in several significant areas. They contain oxygen which reduces the amount of air required for combustion and the amount of heat released per pound of fuel. This results in increased volumetric fuel consumption. Vehicles converted to burn methanol must have their fuel systems modified to deliver twice as much fuel as would be required with gasoline. For ethanol only slightly less fuel is required than for methanol.

Both Ethanol and Methanol have high octane ratings and low cetane ratings without additives. This allows engines designed for alcohols to have higher compression ratios than gasoline engines resulting in improved thermal efficiency and recovering some volumetric fuel efficiency. Cetane ratings for the alcohols are, however, low so their use in diesel type (compression ignition) engines is dependent upon the use of some sort of ignition assist.

Probably the most significant attribute of the alcohols is that they can be ignited at leaner air/fuel ratios than can gasoline. Lean combustion is noted for high thermal efficiency and when the air/fuel ratio is sufficiently lean, emissions of all three of the gaseous pollutants which are currently controlled on passenger cars are minimized. With gasoline it has only been possible to lean engines out to where this occurs by using complicated staged combustion or stratified charge techniques. With alcohols, it may be possible to do so using advanced uniform charge combustion systems.

Gasoline and diesel contain a large number of hydrocarbon compounds and some other constituents such as sulfur. The alcohols are "pure" in that they are single component fuels. This has advantages in that their characteristics can be expected to be uniform from batch to batch, but there are disadvantages. Alcohols will not evaporate in sufficient quantities to ignite at low temperatures so cold starting an engine on alcohol can be impossible in cold weather. With gasoline, volatile hydrocarbons are added which aid cold starting. A similar approach can be used with alcohols or a cold start system using gasoline or heating the air/fuel mixture can be used. Because alcohol is not a "refined" hydrocarbon, it does not contain the trace impurities which deactivate catalytic emission controls.

Test Results from the Three Fleets

A. Fleet I

The modifications which were performed on the Fleet I Ford Pintos to use alcohol fuels are summarized in Table 1.[2] The original three-way catalyst closed loop emission controls were retained, although it was necessary to add small warm-up catalysts to the ethanol cars. Carburetor jetting was revised to match the fuel flow requirements for the alcohols so that the closed loop system could perform as designed. Cold starting is facilitated by using a heated grid below the carburetor on each car, and the water passages in the intake manifolds were enlarged to provide additional heat. The major modification which was made to provide better compatibility with fuel system materials was the addition of a special polypropylene fuel filter. As previously mentioned, two cars were converted to high compression pistons for each fuel. In the aftermarket these conversions would typically cost about $1,000 without the compression ratio change and $2,000 with the revised pistons.

Table 1

FLEET I 8 1980 PINTOS

FUEL:	METHANOL/ETHANOL
EMISSION CONTROLS:	THREE-WAY CATALYST, O_2 SENSOR, EGR, FEEDBACK CARBURETOR
COLD STARTING AID:	HEATED GRID BELOW CARBURETOR
COMPRESSION RATIO:	9.0 or 11.5 to 1
CARBURETOR:	MODIFIED JETTING
OTHER CHANGES:	FUEL SYSTEM MODIFICATIONS FOR MATERIALS COMPATIBILITY INCREASED COOLANT FLOW TO HEAT INTAKE MANIFOLD WARMUP CATALYST (ETHANOL)

Table 2 summarizes CARB's emission tests for Fleet I. The hydrocarbon emissions which are shown are the measured value, multiplied by a correction factor for instrument response (the FID hydrocarcon instruments were calibrated on propane rather than alcohol). Hydrocarbons are reported as unburned fuel without counting the oxygen atoms which would accompany unburned alcohol. The table shows that all the Fleet I cars meet the same emission standards to which they were certified, except the ethanol cars exceeded the hydrocarbon standard. The fuel economy values which are shown in the table are miles per gallon of alcohol. Note that ethanol cars got slighty better fuel economy and that the high compression car got better fuel economy except on the city cycle for methanol. These results are generally consistent with theory since ethanol contains more energy per gallon than methanol and high compression improves efficiency. It is not clear why the high compression methanol car had slightly lower city fuel economy.

Table 2

SUMMARY OF FLEET I EXHAUST EMISSIONS

VEHICLE TYPE	FUEL	HC(1)	CO	NO_x	CITY MPG	HWY. MPG
CERTIFICATION STANDARD	GASOLINE	.41	9.0	1.0	-	-
STANDARD COMPRESSION	METHANOL(2)	.18	2.9	.68	10.0	12.1
HIGH COMPRESSION	METHANOL	.31	5.5	.54	9.8	13.1
STANDARD COMPRESSION	ETHANOL	.70	2.2	.53	12.8	15.8
HIGH COMPRESSION	ETHANOL	.55	2.8	.45	13.5	17.4

(1) Methanol: FID reading multiplied by 1.36 reported without oxygen.

Ethanol: FID reading multiplied by 1.20 reported without oxygen.

(2) Sunken float at 7100 miles caused CO to increase to 20 gm/mi. Another engine in a low compression methanol car suffered excessive cylinder wear at 11,000 miles.

The 1980 EPA fuel economy estimate for the Pinto is 21 mpg so the high compression ethanol cars get 64% of the gasoline fuel economy and the methanol cars get 48% of the gasoline economy (based on 10 mpg). "Gasoline equivalent" fuel economy can also be calculated based upon comparing the heat energy available from a gallon of alcohol. For ethanol the correction factor is 1.934 and for methanol the correction factor is 1.5. The resulting equivalent fuel economies are 20.3 mpg for high compression ethanol and 19.3 mpg for methanol. Therefore, according to the mileage guide, the gasoline version of the Pinto is slightly more energy efficient than the alcohol version.

B. Fleet II

Fleet II consists of 18 methanol and 19 ethanol powered VW's which were produced on the Volkswagen of America assembly line. Table 3 summarizes the modification made.[3] The basic engines used in these cars are the standard short blocks and cylinder heads. The engines are equipped with 12.5 to 1 compression pistons.

Table 3

FLEET II 37 1981 VW'S

FUEL:	METHANOL/ETHANOL
EMISSION CONTROLS:	CLOSED LOOP, THREE-WAY CATALYST, O_2 SENSOR
COLD STARTING AID:	5% ISOPENTANE (METHANOL) GASOLINE INJECTION (ETHANOL)
COMPRESSION RATIO:	12.5 to 1
CARBURETOR:	MODIFIED BOSCH K-JETRONIC
OTHER CHANGES:	MODIFIED IGNITION ADVANCE, MATERIAL CHANGES

The California emission controls including a three-way catalyst and oxygen sensor with closed-loop fuel metering were retained. The Bosch K-Jetronic fuel injection systems were recalibrated for methanol or ethanol, and some revisions were made to the fuel pump which is mounted in the fuel tank. Even with the modifications fuel pumps are only expected to last a year, although none have failed yet. Cold starting is accomplished by adding 5 percent isopentane to methanol and the ethanol cars are equipped with a separate gasoline injection system for cold starts. Volkswagen performed extensive driveability and emission tests on the prototype and it claims that driveability is "commercial" and that the emissions are below California standards.

Table 4 summarizes the results of emission tests performed on Fleet II cars by CARB.[4] As the table shows, the emission standards in 1981 were slightly more stringent than in 1980 for carbon monoxide and oxides of nitrogen. The hydrocarbon standard was changed to reflect methane measurement and subtraction from the total hydrocarbon measurement. The table shows that both the ethanol and methanol prototypes met the 1981 California standards, but the one production methanol vehicle failed to meet the NOx standard. The EPA fuel economy estimate for a 1981 Rabbit with an automatic transmission is 25 mpg. The prototype methanol vehicle got 24.4 gasoline equivalent mpg and the ethanol prototype got 24.5 gasoline equivalent mpg.

Table 4

SUMMARY OF FLEET II EXHAUST EMISSIONS

VEHICLE TYPE	FUEL	HC(1)	CO	NOx	CITY MPG	HWY MPG
CERTIFICATION STANDARD	GASOLINE	.39	7.0	0.7	-	-
PROTOTYPE	METHANOL	.20	1.3	0.2	12.6	17.1
PRODUCTION	METHANOL	.30	0.9	0.8	12.9	16.1
PROTOTYPE	ETHANOL	.25	1.3	0.5	16.3	20.7

(1) Methanol: FID X 1.36 No Oxygen
Ethanol: FID X 1.20 No oxygen

C. Fleet III

The forty Fleet III Ford Escorts were modified by Bill Stroppe and Sons in Long Beach according to specifications developed by Ford. The modifications are summarized in Table 5.[5] As shown in the table, the open loop three-way catalyst emission controls were retained along with EGR. Carburetors were rejetted for methanol, and 5% isopentane is added to the fuel for enhanced cold starting. Compression was increased to 11.4 to 1 by changing pistons, and the vacuum advance was disconnected to reduce oxides of nitrogen emissions. According to a Ford representative, the spark advance modification reduced fuel economy.

Table 5

FLEET III 40 1981 FORD ESCORTS

FUEL:	METHANOL
EMISSION CONTROLS:	OPEN LOOP THREE-WAY CATALYST, EGR
COLD STARTING AID:	5% Isopentane
COMPRESSION RATIO:	11.4 to 1
CARBURETOR:	MODIFIED JETTING
OTHER CHANGES:	WATER AND EXHAUST HEAT ON INTAKE MANIFOLD FUEL SYSTEM CHANGES FOR MATERIALS COMPATIBILITY DISCONNECTED VACUUM ADVANCE

Emission test results for the two vehicles which were tested by CARB are shown in Table 6.[4,6] As the table shows, both cars met the 1981 emission standards. One car also met the ultimate 0.4 gram per mile oxides of nitrogen standard. The EPA fuel economy estimate for a 1981 Escort with a manual transmission is 28 mpg. The corrected result for the 12.9 mpg car in Table 6 is 25 gasoline equivalent mpg. Because the Fleet III cars are equipped with automatic transmissions and are station wagons, the EPA gasoline fuel economy can not be compared directly to the methanol result. The gasoline station wagon with automatic transmission probably gets less than 28 EPA mpg.

Table 6
SUMMARY OF FLEET III EXHAUST EMISSIONS

VEHICLE TYPE	FUEL	HC(1)	CO	NO_x	CITY MPG	HWY. MPG
CERTIFICATION STANDARD	GASOLINE	.39	7.0	0.7	-	-
ESCORT WAGON	METHANOL	.33	4.8	0.41	12.93	18.5
ESCORT WAGON	METHANOL	.31	6.6	0.24	11.6	16.9

(1) HC = FID X 1.36 No Oxygen

D. Durability

Fleet I was the first fleet put into service, so its vehicles have accumulated the most miles. Seven of the eight Fleet I cars have accumulated more than 10,000 miles, although none have exceeded 20,000 miles. During the testing one low compression methanol car became impossible to start. The problem was diagnosed as stuck piston rings and excessive upper cylinder wear. One of the ethanol cars also appeared to be developing a similar problem as indicated by low compression in one cylinder. As of April 30, 1982 the Pintos will be retired from active service for further engine diagnosis and preparation of a final report.

Based upon the wear problems with the cars discussed above, it appears that additional development is needed in engine metallurgy, oils, and lubrication systems for alcohol fuels. It is, however, interesting to note that oil analysis results from tests which were performed for CEC show that the high compression Pintos were experiencing less severe wear than the low compression versions and that the Escorts do not appear to have a wear problem. Therefore, the wear problem may be the result of cylinder wall washing due to poor fuel or combustion control. If this is so, it could be resolved by improving manifold heating and combustion chamber design.

E. Other Tests Performed by CARB

In addition to the standard, certification type "CVS" emission tests which were performed on the CEC alcohol fleets, several other tests were performed including catalyst efficiency tests on the Fleet II cars, selective emission control disablement on the Fleet III cars, and aldehyde measurements on several cars.

Table 7 shows the results of catalyst efficiency tests performed on two Fleet II Rabbits. The tests were performed by emission testing the car with the catalyst then removing the catalyst and replacing it with a straight piece of pipe amd emission testing it again. For methanol and ethanol catalyst efficiencies were similar with hydrocarbon and oxides of nitrogen efficiencies around 80% and carbon monoxide efficiencies close to 90%. The fuel economy column shows that there was a very slight gain in fuel economy, 0.3 mpg, which resulted from catalyst removal.

Table 7

CATALYST PERFORMANCE ON FLEET II CARS

TEST CONDITIONS	HC	CO	NO_x	MPG
ETHANOL				
ENGINE OUT	1.38	10.5	2.49	16.6
TAILPIPE	0.25	1.3	0.53	16.3
CATALYST EFFICIENCY	82%	88%	79%	
METHANOL				
ENGINE OUT	1.14	12.6	1.02	12.9
TAILPIPE	0.20	1.3	0.2	12.6
CATALYST EFFICIENCY	82%	89%	81%	

Table 8 presents the results of a series of experiments performed on the Ford Escorts which consisted of defeating selected emission controls and measuring emissions.[7] The cars were tested with all emission controls operating, then the air injection system and the exhaust gas recirculation system were each deactivated for an emission test. Finally, both systems were deactivated for testing. Table 8 shows that the results are consistent with the function of the emission controls; deactivating the air injection system increased hydrocarbons and carbon monoxide and deactivating the EGR increased oxides of nitrogen.

Table 8

EFFECT OF DEFEATING EMISSION CONTROLS ON A FLEET III CAR

TEST CONDITION	HC (1)	METHANOL (2)	FORMALDEHYDE	CO	NO_x
BASELINE	0.33	0.015	0.008	4.8	0.41
NO AIR	0.70	0.39	0.015	28.0	0.37
NO EGR	0.52	0.08	0.031	4.4	1.13
NO AIR & EGR	0.70	0.42	0.083	23.5	0.74

(1) FID X 1.36 No Oxygen

(2) Oxygen subtracted so that Methanol could be compared to HC

were higher than the combined no Air & EGR test results. This probably occured because the Escorts have dual bed catalysts. The first bed is a reducing bed and the second is an oxidizing bed. Air is delivered between the two. Reducing catalysts typically convert oxides of nitrogen to nitrogen and oxygen, but they also make some ammonia. When no air is delivered to the oxidizing catalyst, the ammonia is exhausted intact, however, when air is delivered to the oxidizing catalysts the ammonia is converted back to oxides of nitrogen. This latter conversion is probably what was happening during the "no EGR"tests since the air injection was operating for that test.

The tests on the Fleet II and Fleet III cars with emission controls removed or deactivated were performed to help correct a common misconception, Many people, including some California legislators, either believe that alcohol fueled cars have zero emissions, or that their exhaust emissions are so low that emission controls are not necessary. The test results shown in Table 7 and 8 clearly demonstrate that while alcohol fueled cars can meet California's stringent emission standards with emission control systems, uncontrolled alcohol vehicle exhaust emissions are significantly higher than current California standards.

Table 9

ALDEHYDE EMISSIONS

VEHICLE	FUEL	ALDEHYDES	ENGINE OUT ALDEHYDES	CATALYST EFFICIENCY
1981 RABBIT	METHANOL	.03-.04	.08-.10	60-63%
1981 ESCORT	METHANOL	.01	.10	90%
1981 RABBIT	ETHANOL	.03	.22	86%
17 CARS WITH CATALYST	GASOLINE	.015	NA	NA
3 CARS W/O CATALYST	GASOLINE	.18	NA	NA

In addition to measuring hydrocarbons, carbon monoxide, and oxides of nitrogen, the aldehyde emissions were measured from several cars both as "engine out" emissions, and after the catalysts. The results of these measurements are shown in Table 9. For comparison the results of aldehyde measurements performed by the South Coast Air Quality Management District[8] on gasoline cars which were being tested by CARB are also shown. The average of 17 in-use catalyst cars on gasoline was 0.015 grams per mile of aldehydes. The aldehyde emissions from the Rabbits were about twice as high with emissions of 0.03 to 0.04 grams per mile on methanol and 0.03 grams per mile on ethanol. The engine out aldehydes were higher on ethanol, but so was the catalyst efficiency. The methanol Escort had lower aldehyde emissions than the gasoline cars. It is also interesting to note that the gasoline cars without catalysts had higher aldehyde emissions than the methanol cars' engine out emissions. It is important to note that the in-use gasoline vehicles had accumulated significantly more miles than the ethanol and methanol cars because catalyst efficiency normally deteriorates with mileage accumulation.

III. Future Alcohol Engines

While the cars being tested by the CEC and CARB represent production cars which incorporate the necessary modifications to provide good performance, emissions and efficiency on methanol or ethanol, further optimization studies need to be done. Figure 1 shows the general dependence of emissions and efficiency upon equivalence ratio (defined as actual air/fuel ratio divided by chemically correct air/fuel ratio). The figure shows that as the air-fuel ratio is made leaner, efficiency increases, NOx increases then decreases, CO decreases, and HC (UBF) decreases then increases as combustion efficiency drops and misfiring occurs.

Current 3-way catalyst cars and the Fleet II and Fleet III cars operate very close to an equivalence ratio of 1.0, the chemically correct value, in order to optimize catalyst performace. However, this results in some penalty in efficiency.

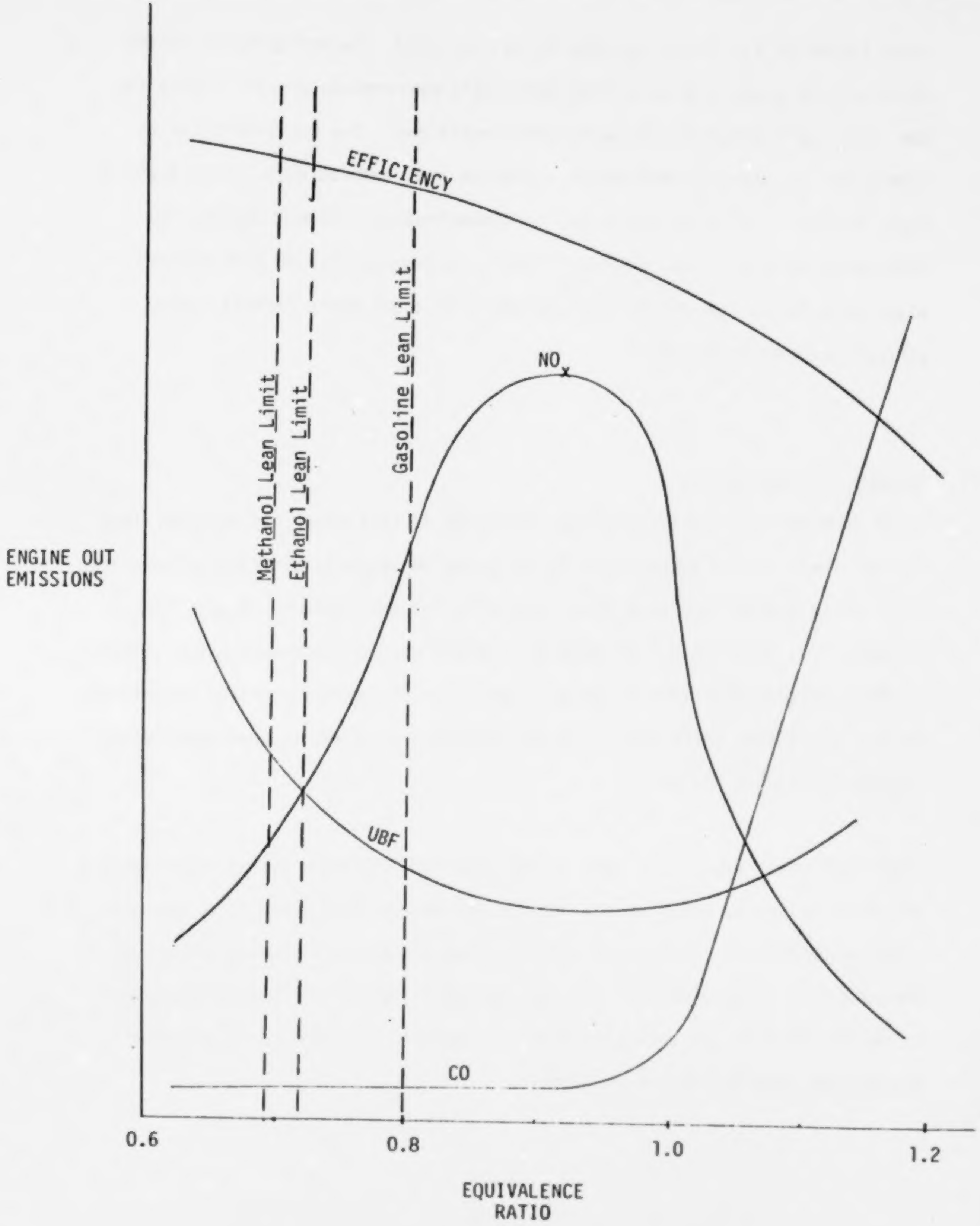
In order to improve efficiency, it is desirable to operate engines at leaner equivalence ratios. This approach is limited by the fuel's lean flamability limit. As shown in the figure the lean limit for gasoline is an equivalence ratio of about 0.8 based upon the average of part throttle and wide open throttle engine tests performed for Department of Energy by Pullman.[9] At that point, NOx emissions are still relatively high. If further enleanment is needed to meet NOx standards, staged combustion or stratified charge techniques are required. The figure shows that the lean limits for methanol and ethanol are closer to an equivalence ratio of 0.7, where further reductions in NOx are achieved. Therefore, future developments of spark ignition engines for methanol should be based upon lean combustion for improved efficiency and low engine out NOx. Sophisticated fuel metering systems such as port fuel injection would probably be required since good fuel distribution is essential to avoid lean misfire problems. An engine designed along these lines could also incorporate an oxidation catalyst and EGR, as needed to meet emission standards.

Another area where significant research is taking place is in the area of unthrottled cylinder fuel injection alcohol engines which are similar to diesel engines. For these engines to operate, it is necessary to provide some sort of ignition assist, such as pilot diesel injection or a spark plug. The major advantages of engines designed along these lines are that they have little or no particulate emissions, and catalysts can be used to oxidize their HC and CO emissions. MAN in Germany has demonstrated a spark ignition methanol engine based on one of its diesel engines in bus service.[9] The MAN methanol engine appears to be capable of providing comparable performance and efficiency to the diesel without producing particulate emissions. The California Energy Commission is currently working on a methanol bus demonstration project which would involve several manufacturers in demonstrating methanol engines in California municipal bus service. Diesel type engines fueled with ethanol might be suitable for use in farm equipment in areas where biomass based ethanol could be produced.

IV. Summary and Conclusions

Based upon the information and data presented in this paper, it is clear that alcohol fuels can be substituted for gasoline in properly modified automobiles. Tests performed by CARB have shown that vehicles developed by Alcohol Energy Systems, Inc, Volkswagen, and Ford are capable of meeting the emission standards to which the vehicles were originally certified on gasoline. Fleet experience to date shows that there are still some problems with engine wear which will require additional analysis.

Additional work needs to be done in the areas of lean burn and cylinder fuel injected engines to optimize the engines for methanol or ethanol, rather than gasoline or diesel. The author believes that optimized alcohol engines have the potential to provide low emissions and good thermal efficiency compared to current engines and that with continued progress alcohol could become a significant vehicle fuel in the future.



EFFICIENCY
NO$_x$
UBF
CO
Methanol Lean Limit
Ethanol Lean Limit
Gasoline Lean Limit
ENGINE OUT EMISSIONS
0.6
0.8
1.0
1.2
EQUIVALENCE RATIO

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Political and Public Relations Aspects
of
Motor Vehicle Emission Inspection Programs

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Political and Public Relations Aspects of Motor Vehicle Emission and Inspection Programs

I. Introduction

Technical design, mechanic training, public information, and political reaction are four of the many elements that must be considered in the implementation of a motor vehicle emission inspection and maintenance program (I/M). These elements are interrelated and the program's success is dependent upon all of them.

In most cases resources are limited, particularly in the early stages of design and operation. It is therefore necessary to establish priorities and carefully plan the timing of resource utilization for each of the elements.

There is no doubt that the program's ultimate success requires sound technical design. The operational aspects of the program and improved services from the repair community will also have a significant impact on the reaction of the public and concerned political bodies. But, unfortunately, test details often overshadow other needs, even though proper consideration of political and public information activities are essential for program survival.

II. Political Considerations

In most areas legislative authorization or funding authority is necessary to start a program. Elected officials are therefore involved at the beginning and rightfully feel both responsibility and accountability for the program. Hundreds of thousands of people are affected, and the average elected official will respond to the reaction of a small minority of constituents. It is therefore essential that the agency establish rapport with appropriate legislative bodies, and that information be provided to them on a timely basis throughout the design and operation of the program. Some legislators will never be program supporters. However, it is important that they have sufficient confidence in the agency to call when they have questions or a need for information. While their response may not be favorable, most of them will respect and utilize factual information. Building this confidence must start during development of enabling legislation and continue throughout the life of the program.

I/M in Washington, as in many other areas, was authorized to avoid the sanctions in the Federal Clean Air Act. While there was some support for vehicle inspection as an air pollution control measure, there is no doubt that the program was authorized solely to protect funding for transportation projects and other programs.

This attitude immediately places the agency in a defensive posture. It is difficult to start a program that will be initially opposed by most of the public because of its cost and inconvenience, and by governing political bodies because they felt coerced into authorizing the program in the first place.

The concern of the Washington Legislature was so great that they retained total oversight of the program, including approval authority over all departmental regulations governing program design and operation. This legislative involvement is a mixed blessing. Total oversight is unworkable and probably illegal. From a practical standpoint it is simply impossible to have legislative committees approve every minor regulation change that may be needed. On the other hand, oversight of major program elements is helpful to the agency, as it provides a mechanism for legislative contact and involvement in major decisions. If the legislature approves the fees, inspection area boundaries, and basic elements of program design, they are not only aware of the program, they assume a responsibility that might otherwise be avoided.

In Washington the law prohibits inspection stations from being operated by government agencies or anyone in the business of vehicle repair. With these limitations, a contract program was proposed. The initial program design was the subject of numerous interim legislative committee hearings. Responding to many diversified ideas complicated our Request for Proposal (RFP), and perhaps slowed the process. In actuality, three different systems were considered and included in the RFP. Bids were allowed for single lanes, franchise operations or the entire system. Bids were received only for a single contractor system. The interim committee review was cumbersome but provided advice to the agency and assisted in the establishment of rapport with many legislators, including those for and against the program.

The official committee hearings were supplemented by correspondence to keep the legislators informed and involved. They were advised of proposed regulation changes that became necessary during final program design, and were sent copies of the public information material as it was developed. All legislators from the inspection area were notified prior to the start of the program, and advised of the public reaction that was expected. The net result was a reasonably informed key core of legislators that would be faced with the majority of the complaints when the program started. Thus far four bills to repeal the program have stalled in two legislative sessions. At least one of those bills was tabled by an "anti" that knew the facts.

Any agency implementing an I/M program must recognize and understand the impact on, and by, governing political bodies, and work with those groups to avoid disastrous conflicts.

III. Public Information

Adequate public information is one of the most overlooked and underemphasized needs in technically oriented programs. Vehicle emission inspection and maintenance is one of the few air pollution control activities that directly impacts the individual citizen. Public involvement and education are essential to acceptance of I/M.

Informing the public is in itself a major challenge. The Washington State Legislature held many hearings in 1979, before authorizing the program. Public involvement was typically limited to special interest groups. During the following months, the legislative oversight hearings and workshops conducted by the department were open to the public. Attendance was again limited, and the response was primarily to oppose the program, rather than to comment on the proposed regulations.

An 18-24 month lead time is necessary for a program to become operational, but it is difficult to obtain public interest that far in advance. The timing of the public information program therefore becomes critical. An extensive effort made too early will not have adequate impact. On the other hand, there is a tendency to wait too long or ignore the emphasis that must be placed on informing and educating vehicle owners.

In many areas basic support is available, but must be developed. Many people support a clean environment. However, they may not recognize that an air pollution problem, particularly one caused by carbon monoxide, even exists. Relating their vehicle to the problem is even more difficult. Information must be produced and distributed to explain the problem, the sources of the pollution, and the solution.

In Washington it was decided to place major emphasis on the public information program. The technical design was handled by existing air pollution control program staff. The first individual hired specifically for I/M was a public information officer. EPA provided a $500,000 "seed" grant to the department on a one-time basis to encourage and assist in total program development. $225,000 of this grant was initially allocated to the public information activities.

The information effort had to be carefully designed. The state I/M law requires the department to provide specific information to the public. On the other hand, a "hard sell" that could be interpreted as an agency justifying its existence would receive severe criticism by both the public and the legislature. Therefore, the entire effort was aimed at education rather than promotion.

The department contracted for professional assistance to design the total program and to establish a timing sequence for specific activities.

The educational program was developed to begin on a gradual basis, approximately a year before the inspections became mandatory. It was the intent to reach a peak in the public information activities in the three-month period before mandatory testing and to continue the program for at least a year after testing began.

Four general phases of the information program were defined. These included prevoluntary, voluntary, premandatory, and mandatory time frames.

The prevoluntary phase operated between January and June 1981. The basic program logo, initial brochures, and other materials were developed and distributed. Agencies, organizations, and the news media were contacted. An ad was placed in the Seattle Mariner baseball program and public service announcements were developed for use on the Kingdome message board during the baseball games. Two 30-second public service announcements produced by EPA were adapted for use in the Seattle area. A slide show was produced discussing Seattle's air pollution problem and the forthcoming I/M program. The major thrust of this phase was to provide information on the air pollution problem in the Seattle area, and the contribution of vehicles to that problem.

The concept of vehicle inspection was gradually introduced and became more pronounced during the voluntary phase which operated from July to December 1981. Initially, it was planned to utilize the contractor-operated inspection stations for the voluntary test program. However, they could not be completed on time and it was necessary for the department to conduct its own voluntary emission testing program by providing free tests at special events and at regular locations on a published schedule. Approximately 18,000 vehicles were tested during this six-month period.

Television and radio public service announcements were developed to encourage participation in the voluntary test program, to describe pollution caused by motor vehicles, and to explain the purpose of emission testing. Support from the media was outstanding. One local radio station "sponsored" our voluntary emission tests at the 1981 Auto Show in the Kingdome. In addition, they produced several public service announcements, as well as a brochure and special programming on vehicle inspection.

A grant was provided to the Puget Sound Leagues of Women Voters to establish a speakers' bureau. They utilized the I/M slide show in over 50 presentations.

A key feature of this phase was installation of a hot line in September 1981 to handle questions on the I/M program. The hot line was publicized extensively through the news media, and has received up to 600 calls per day. It is still in use and will be maintained as long as needed.

In anticipation of an increase in complaints on automobile repairs the department contracted with the State Attorney General's Office in Seattle to establish a consumer education and repair complaint mediation program.

The premandatory phase operated from October to December 1981, as an accelerated effort from the voluntary phase. An insert on I/M was developed to include with the notice issued 90 days in advance of vehicle license renewal, by the Department of Licensing.

Editorial board conferences were held at major newspapers in December. This provided an opportunity for top management of the department to discuss the program and anticipated problems with key editorial writers and staff. We found that a well informed press is inherently fair. This is ultimately beneficial, even though that fairness may result in justifiable criticism about some activities.

The agency's I/M staff participated in a one-day media training session, including simulated television news interviews. This was conducted to help all staff involved relate to the media.

During this phase an advertising firm was retained to develop materials and to recommend advertising media. They also prepared a timing sequence and budget for the advertising, based on limits established by the department.

The same firm conducted a public opinion poll in mid-December 1981. The primary purpose was to determine if our activities had been successful in informing the public of the forthcoming mandatory program. It also provided an opportunity, however, to obtain information on public opinion regarding air pollution and the need for vehicle inspection. We were pleasantly surprised that the majority of motorists recognized an air pollution problem in the Seattle metropolitan area and agreed that the auto emissions test would help alleviate the problem. Over 90 percent were aware of the forthcoming auto emission tests, and 70 percent said they favored the program. Even when considering the limitations of the poll, it indicated that the efforts to inform the public were highly successful, and we were certainly encouraged by the level of public support.

The final effort in the premandatory phase was to conduct a news conference and press opening at selected test stations three days prior to the start of mandatory operations. This provided media representatives an opportunity to view the system, to test their vehicles, and to discuss program operations with the contractor.

The mandatory phase began in January 1982 and is scheduled through December 1987, the life of the vehicle inspection contract. Brochures were developed to give to motorists at the test stations. A pass brochure explains the test and thanks the drivers for being part of the solution to the air pollution problem. A fail brochure is distributed, when appropriate, to aid motorists,with repair requirements, warranties, and licensing procedures.

The paid advertising developed by the agency in the previous phase was purchased on radio, in four newspapers, and on the interior and exterior of buses. Ads were run in newspapers during the first four weeks of the program, utilizing a total of 12 ads in four papers. 110 radio spots were purchased from seven stations during the first week. These spots were obtained during morning and evening commuter hours. This effort was reduced to 76 spots during the last three weeks in January, 62 during a two-week period in February, and 31 during one week in March. Interior transit posters were used during January and February, and exterior bus posters in March and early April. The department will distribute a 30-second television PSA and six radio PSAs to broadcast outlets in June. From here on out program feedback, and resources available, will dictate the level of effort and specific activities conducted in the public information program.

The key elements in the information effort included: (1) Emphasizing the need for public information and allocating necessary resources. (2) Early development of media contacts which resulted in fair reporting and general media support. (3) Use of commercial firms to design an overall program, to establish a timing sequence,and to develop materials.

Complaint response is an essential part of public relations. There will be complaints about the program in general. The public will be concerned about the exemptions, or lack thereof, the inspection area boundaries, the impact of fees on various social strata, the test procedures, repair limit waivers, and anything else that can, in any way, be interpreted to be inequitable. The program impacts hundreds of thousands of people so the potential for complaints is great. A well conceived information program can help alleviate this problem, but a complaint response capability remains essential.

The Washington program is not large in comparative terms. It involves approximately 675,000 vehicles each year. During the latest one-month reporting period 4,778 calls were received on the hot line, and only 98, or two percent, of those calls were complaints. In addition, 65 written complaints were received directly or via the Governor's office. In the same period of time over 50,000 vehicles were tested, and approximately the same number received notices that tests would be required before relicensing. The number of complaints can seem overwhelming at times, and can certainly influence legislative opinions. However, in perspective, the impact can be managed.

IV. Conclusions

Developing and implementing a motor vehicle emission inspection and maintenance program is a major challenge for any agency. Recent experience has reinforced our opinion that legislative rapport and a public information program are absolutely essential. Continued legislative involvement and confidence in the implementing agency must be developed. The public must know that a problem exists, the reason for the program, and the purpose of each aspect of its design. While it is not possible to anticipate all problems or questions that may arise, many elements of program design will obviously be controversial and need to be properly explained.

V. Recommendations

1. Technical design should consider public needs. These include costs, convenience, flexibility, test validity, etc.
2. Emphasis should be placed on improved services from the repair community.
3. Legislative involvement should begin with initial authorization of the program and be continued throughout its design and implementation.
4. The public information program should begin at least one year prior to start of the mandatory test. Major emphasis should be placed on this effort with the activities carefully timed.
5. Materials should be factual and the facts documented.
6. The news media should be contacted early and advised honestly on the pros and cons of the program, and problems that are anticipated.
7. Every technique available for public information should be explored and used if possible. Public service announcements, paid advertising, free voluntary inspections, news releases, brochure distribution, and mass mailings are examples to consider.
8. Professional assistance should be retained for total program design and for specific implementation, if possible.

Vehicle emission inspection programs are a composite of many interrelated activities that must be considered together, but emphasized individually to make best use of available resources at specific times. An ill-conceived technical design will undoubtedly result in major problems or program failure. But, neglecting the political and public information aspects of the program can undermine the best of test systems.

SESSION V

I/M EFFECTIVENESS

START-UP PROBLEMS--TRAINING--ENFORCEMENT; THE CENTRALIZED CONTRACTOR APPROACH

PREPARED FOR:

THE NINTH ANNUAL NORTH
AMERICAN MOTOR VEHICLE
EMISSIONS CONTROL CONFERENCE

PREPARED BY:

JOHN R. WALLAUCH
CALIFORNIA I/M PROGRAM MANAGER

INTRODUCTION

I would like to thank the committee for the opportunity to speak to this conference. First, I would like to present a brief overview of the California program; second, identify effectiveness features of a centralized contractor operated I/M program, and last I will touch on general I/M items such as: start-up problems, training, and enforcement.

BRIEF HISTORY AND DESCRIPTION

California has since 1963 been involved in licensing of automobile repair facilities and mechanics to inspect and repair emission control devices, including installation of retrofit systems on vehicles changing ownership or upon initial registration into the state.

This early program, which is still operational statewide, became known as the "Blue Shield" program because of the shape and color of the official station signs. By definition, this program is known as a decentralized mandatory maintenance, or parameter adjustment program.

In 1974, legislation was enacted requiring a separate program in the greater Los Angeles area for inspection of vehicles utilizing the centralized approach to identify the gross emitters.

Initial legislation directed a phased State operated centralized program of design, trial program operation, change of ownership and then annual inspection. Beginning in September 1975 and lasting until March 1978, a trial program was operated in the small town of Riverside, accumulating over 50,000 volunteer tests. Subsequent legislation withheld implementation of the annual phase and directed the department to study the effectiveness of allowing a contractor operated change of ownership phase.

Following legislative delays, a contract to provide contractor testing of vehicles upon change of ownership was signed on June 30, 1977, and actual testing began on March 19, 1979, with a centralized contractor operated change-of-ownership program implemented in the greater Los Angeles area, known as the South Coast Air Basin (SCAB).

Through the bidding process the State selected Hamilton Test Systems (HTS) to be its contractor for a five (5) year term.

This program has been in operation for over three years and accounts for approximately 1.5 million inspections per year (this includes 300,000 tests conducted in the fleet portion of the program).

Vehicles were initially subjected to an idle only emission standards test of HC and CO and a complete underhood visual inspection. During the second year of operation dynamometers were installed to collect emissions data at cruise mode. On January 2, 1982, a full loaded mode testing was initiated, with pass/fail at both cruise and idle and NOx cutpoints being added at cruise for nitrogen dioxide (NO_2), a problem in the Los Angeles Basin.

PROGRAM EFFECTIVENESS

Program emission standards coupled with visual underhood inspections resulted in an overall failure rate (or stringency) of 46 percent under the idle pass/fail segment of the program (30% emisssions, 16% visual underhood).

Since the adoption of loaded mode cutpoints including diagnostic algorithms and modified underhood, the failure rate increased to 52 percent (42% emissions, 10% visual). This increase is primarily due to the cruise emission failures.

Emissions reductions as compared to before and after repairs resulted in an average reduction for HC of 39 percent at idle and 29 percent at cruise; the CO reduction was 34 percent at idle and 10 percent at cruise. NOx emission reductions were measured at 15 percent.

Vehicles that are in need of repairs exceeding the $50 cost limit are granted a waiver after the low emissions tune-up is performed. Our current waiver rate is running at approximately 22%. Vehicles receiving waivers are achieving emissions reductions of approximately half the value of what is recorded for vehicles passing after repair. The average cost of repairs is currently recorded at $30 with the average model year undergoing inspection being 1974.

CENTRALIZED I/M EFFECTIVENESS

Inherent in the design of the centralized, contractor operated I/M inspection concept are certain advantages not available in the decentralized concept: vehicle testing and repairs are entirely separated thus allowing for program integrity; emission measurements are done quickly and efficiently with trained personnel; and accurate before and after repair emission readings are recorded and computer stored for subsequent analysis of program effectiveness. Program quality assurance is easily maintained due to the low number of inspection facilities, personnel and instruments, which can be monitored efficiently by a small state staff. The reliability of before and after repair test results allows accurate assessment of the automotive repair industry effectiveness and identifies those facilities in need of training or enforcement actions.

Data management is greatly enhanced through the use of centralized record storage and analysis. Also consumer protection (as distinguished from consumer convenience) is maximized under the centralized inspection concept, due to the reasons stated and coupled with the close state monitoring and control inherent under a centralized system.

In assessing the effectiveness/cost effectiveness of a contractor operated centralized I/M program we identified the following considerations by which the contractor approach would benefit the state:

1. The state would not be required to put up large sums of front money for capital investment in land, buildings and equipment prior to the receipt of any revenues.

2. A Private contractor can move rapidly and has more flexibility in the hiring, training and task assignments of personnel, allowing greater likelihood of meeting program target dates.

3. A contractor could move quicker in the areas of site acquisition and facility construction than under normal State procurement procedures.

4. The State cost estimates, particularly with respect to leasing and construction costs, might be low, whereas by the terms of the contract, the contractor is bound by their price quotes.

5. Should the Legislature decide not to continue the program beyond the existing contract period, the State at the end of 5 years could terminate the program with minimal cost to the State and without a large layoff or relocation of State personnel.

6. Should the State determine at a later date that the State could more effectively operated this program, the contract contains provisions for supplantation.

7. The contract contains requirements for key State approvals and imposes penalties for nonperformance, thus State control of the program is assured.

8. With respect to land and building procurement, the contractor approach is perhaps more acceptable to local governments since the State approach does little for their tax base. The contractor, on the other hand, pays a considerable amount in taxes. This factor seems to facilitate the private contractor's ability to obtain use permits, building permits, and to clear other local ordinance requirements. We later found this not to be always true.

Other considerations wherein the contractor approach could be cost effective are:

- A contractor is expected to have higher operating efficiency because of the profit incentive and operational flexibility, thus reducing costs.

START-UP PROBLEMS

Start-up problems affecting our program were minimal and those that are recalled can best be grouped into two categories.

The first deals with allowing (or not allowing) sufficient time to accomplish construction activities resulting in a delay of the program schedule; the second involves activities associated with gaining local approval (permits) to allow facility construction.

1. California's start-up date slipped 2 1/2 months primarily due to bad weather, yes it can even happen in sunny southern California! Predicting the weather has been an elusive science but one area of major impact when dealing with the preparation of building sites. We allowed more than a full year for site selection and construction but delays in gaining site approvals, coupled with frequent rains, resulted in a 77 day delay.

2. The second and probably most exasperating problem area deals with the difficulties associated with gaining local city/county building and utility permits.

   Our program suffered major setbacks by the refusal of some city planning commissions to approve building permits. This resulted in major network re-designs to achieve contractual compliance to maximum driving distances. This problem was a particular concern in the California change of ownershp program due to the limited number of fixed site stations (15) to be built for the change of ownership phase. An annual program would allow for a denser concentration of stations and consequently allow more flexibility in relocating locations and maintaining acceptable average travel time and distance to reach test stations, for a majority of the population.

3. Other difficulties encountered with local bodies were: special construction restrictions that required building setbacks that reduce queue space; prohibitions on signs; certain building code aesthetics; and outside pressures from local citizen groups that wanted no part of the program located in their neighborhood.

4. Other problems that may only be unique to California are:

   - Initially we allowed our DMV offices to collect the test fee. This proved to be a problem, in that, at times, collection of fees was overlooked, and also a substantial number of vehicles were being tested but failed to return to the DMV office and consequently paid no fee. This circumstance required a renegotiation with the contractor to collect fees at the test centers, a development that increased our cost per test.

   - There were a number of built-in fee adjustment provisions in the California contract. When tied to a cost-of-living index these can trigger large and generally unplanned increases in program costs and may cause test fee increases which, of course, are quite unpopular.

TRAINING

As a wise man once said: "you can inspect cars on a daily, rather than annual basis, and it won't achieve one iota of emissions reduction unless the cars are properly adjusted, tuned and repaired".

Legislation establishing the California program directed the department to conduct orientation or training seminars. During our trial program we determined that is was not practical to hold an all day training session. We opted for the screening of mechanics for competency in vehicle repair by the development of a comprehensive four module examination. This was coupled with a one hour seminar using 35 mm slides and a taped narrative to explain the I/M program and required repair procedures.

A formal training packet, a first by any state, was developed as a comprehensive course of study in all subject areas that a mechanic is required to know and use in order to repair vehicles failing an I/M program. Final development and production of the packet was performed by Colorado State University and with the help of the EPA.

Representatives from interested sections of the automotive industry, and educational and governmental representatives participated in the development of the material. This effort resulted in the publication of a 51 hour, four module training packet which complements the examination and is now used statewide with the addition of a 5th Module.

The training material uses a conceptual rather than a directional approach to maximize the relevance and timeliness of material.

Course material consists of a series of approximately six hundred and fifty 35mm slides and instructional sheets containing the narrative and key points for each section of the training, and instructor demonstration sheets for shop demonstration.

Course contents:

Module No. 1: Introduction to Mechanics Licensing for Motor Vehicle Pollution Control Stations.

Module No. 2: Engine Theory, Electrical and Spark Control Systems.

Module No. 3: Fuel Systems and Emission Control Systems.

Module No. 4: Engine Diagnosis and Test Equipment Usage.

Module No. 5: Centralized Vehicle Inspection Program Requirements.

This additional training is made available through local adult education schools and colleges which provided training on an open entry - open exit basis. Interested persons who failed one or more of the examiniation modules may attend only the module(s) needed and be re-examined in the subjected module of their particular deficiency.

Attendance at the 51 hour training course is voluntary, but a mechanic must attend a seminar and pass all modules before he/she is granted a license allowing the repair of vehicles failing the inspection. To date, over 6,600 mechanics have become VIP licensed and over 12,000 have attended the seminars.

ENFORCEMENT

The California Vehicle Inspection Program enforcement efforts are organized into two basic parts: 1. Contractor Compliance; 2. Repair Industry Enforcement. Contract compliance and test center operations are monitored and enforced through surveillance performed by state quality assurance teams, and computer verification of test and maintenance data tapes.

Quality assurance teams verify the soundness of the test equipment by measuring the accuracy of analyzers using six point calibration gases, as well as observing test center housekeeping and the activities of inspection center personnel. These random unannounced visits to each test center occur approximately 3 times each month.

The contractor is required to record all equipment calibration checks and maintenance activities on automated records maintained at the test centers. These data are forwarded to the state each month for analysis. Special studies and covert investigations are conducted to gather data on selected contractor activities in order to assess contractual compliance.

The results of these unannounced visits have shown the contractor test equipment to be within acceptable calibration limits over 95% of the time. In the last three years there were seventeen lane closure notices issued when the test equipment could not be corrected by simple spanning or zeroing.

Repair industry enforcement of the centralized inspection generated-repairs are accomplished through the use of EDP records and field surveillance. Automated data collection allows for the analysis of after repair emission reductions, average repair costs, and success of repair actions. In addition, ongoing surveillance is conducted by a staff of state representatives. Computer generated reports gathered from repaired vehicles identify both repair facilities and mechanics who receive low scores on performing appropriate repairs. These reports provide such specifics as the percentage of vehicles passing or receiving waivers upon reinspection, per facility and mechanic; the average cost of repairs; and when cost limitations have been exceeded.

An adjunct to the contractor operation is a decentralized inspection and maintenance fleet program. This provision is available to owners of 10 or more vehicles who may elect to inspect their own vehicles on their own premises. These licensed fleets are required to maintain required test equipment, follow set procedures, and maintain records. State representatives make unannounced visits to these fleet stations on an average of every 50 days, in order to make calibration checks of HC/CO analyzers, verify maintenance of records, and reinspect vehicles in inventory (in the case of new/used car dealers).

Revocation of suspension of a repair facility or qualified mechanic's license is accomplished through filing a formal accusation with the State Attorney General's Office. When fraud or unfair business activities are uncovered local District or City Attorneys may pursue a civil action on the case.

CONCLUSION

In conclusion, the California experience in controlling in use vehicle emissions is varied and complex in its application. I trust I have been able to impart to you our centralized I/M experiences and I will be pleased to try and answer any questions you might have. I would like to express my appreciation for this opportunity to talk with you and for your kind attention.

SPEECH DELIVERED BY JAMES F. McGUIRK DEPUTY COMMISSIONER, NEW YORK STATE DEPARTMENT OF MOTOR VEHICLES, NINTH ANNUAL NORTH AMERICAN MOTOR VEHICLE EMISSIONS CONTROL CONFERENCE, SCOTTSDALE, ARIZONA

May 7, 1982

Welcome to the last and final meeting of the State and Territorial Air Pollution Program Administrators and to the first reunion of the North American Motor Vehicle Emissions Control Conference.

Eighteen months ago in Atlantic City, I recommended that we all move out of our offices into the PR office - that we become better salesmen for Clean Air.

Since that time in October 1980, we have seen a political blockade on the Environmental Protection Agency and a land, sea and air assault on the Clean Air Act - only last week was that blockade lifted.

Is there no objective criteria for judging unhealthy air? Is air partisan? Is air a problem? And is a problem - like beauty - in the eye of the beholder?

I say our house is on fire - and we at this conference are hanging wallpaper.

I say that political and public relations issues should be our focus and yet out of 2-1/2 days of conference, we have spent only 30 minutes on the frontal assault. We should have sessions on "How to Lobby Congress" - "How to Sell Snake Oil."

But wait, I go too fast.

Let us look at some facts, make some observations, and raise some questions.

And let me begin with the fact that I should know most about - and that is, what's happening in New York.

START-UP

New York launched its emissions inspection system on January 1, 1981, in 3,000 licensed inspection garages equipped with a single contractor's computerized analyzer and a great deal of public controversy and anger among service station owners. Now, 16 months later all seems to have changed. There are now 4,200, not 3,000, inspection stations handling over 3.7 million vehicles. The average inspection station has doubled its inspection business as well as receiving twice as many dollars for conducting New York's annual safety and emissions inspection. The public, from all indications, shows an understanding and acceptance of the program, its goals and its merits.

PROBLEMS 3

In 1980, when we were starting this program, we viewed our problems as three. First, the need to provide the public with a quality emissions inspection. That is, an inspection that is controlled, objective, and uniform in its delivery in 4,000 garages. Second, the need to provide quality repair. That is, a repair analytically diagnosed and effectively repaired the first time. Finally, the need to provide information on the value of the system both for clean air and fuel efficiency to all opinion makers and the general public.

QUALITY INSPECTION

Our answer to the problem of providing quality inspection in thousands of garages was to designate **one contractor** to produce the most accurate computer controlled gas analyzer we could obtain. The analyzer had to provide written test results and give an indication of probable repairs to the customer, as well as to automatically record all inspection data.

By contract, we directed the manufacturer to train all of the inspectors and routinely calibrate and maintain the equipment, monthly. We expanded the state inspector training during 1981, issued training newsletters and bulletins. We met with the industry at every chance in group training sessions and meetings to assure the industry that the program was viable and cost effective for them.

We were there when any serious service or mechanic problem arose between the garage and the contractor.

We designed a computer program that would handle the inspection station tapes, analyze every inspection record for system statistics, enforcement and control.

Our experience with this plan to date has been edifying. The private garages whose noisy reluctance to accept the single machine concept and the required monthly maintenance are now a supportive link in our system.

QUALITY REPAIR

Our answer to the quality repair problem was to set up a voluntary 16-hour mechanic training program for emissions systems repair. We used the National Center EPA course by Colorado State University. We trained master instructors, 75 so far, and aided them in setting up training courses throughout the area. We have found through pre- and post-tests that the mechanics have improved their skills by 30 points. We monitor these courses and seek course and instructor changes where necessary. We are publicizing these trained mechanics by giving them distinctive arm patches and signs for their stations.

We have already trained over 1,600 mechanics and, in the future, we plan to train thousands more.

PUBLIC INFORMATION - Or How to Sell Something You Can't See, Smell or Taste

The third problem, the recognized need to win the support and acceptance of the program by opinion makers and the general public was visible within the news media daily. We set to work by designing public information campaigns for 1981 and 1982.

A grant of $500,000 by EPA to run the PR program was essential for its success. But those money days are gone. During the first year, we informed the public about the clean air problem, that better air meant better health, and that well-tuned cars are fuel efficient.

In 1981, we required all vehicles to be inspected, but repairs for failed vehicles were voluntary. This gave us one year for the public to familiarize themselves with the emissions inspection process.

This year, in 1982, we had to inform the public about the need for repair upon failure, what kind of repairs might be necessary, what to look for in a repair shop, and how to apply for a state waiver if repairs were going to be excessive.

Our attempt to influence and gain the support of opinion makers was primarily through an Advisory Board which discussed program issues and made suggestions to the Commissioner. We met with as many legislatures and opinion groups who would listen. We issued updates and very comprehensive status reports to keep our legislators informed.

From the start, there were always program critics, primarily on the state representative level, who have been steadfast and unwaivering in their criticisms. But this, too, in retrospect helped to keep us keenly aware that we had to answer every question and have plans ready for every contingency, or as they say, you can't be creative without criticism.

As we approached our mandatory repair phase, we recognized new potential problem areas. The need for repairs, a waiver program, and the question...would repairs become so excessive that a public outcry would stop the system? The garages, there are 4,200 of them now, seemed ready. They were trained, had one year's experience in testing, and generally approved of the system. About 1,000 mechanics had been trained in emissions repairs and all of our training agents had a two-week training period.

The program acceptance from the public was high, our public opinion survey indicated that 66 percent of the residents of the New York Metropolitan Area rated air pollution as a very serious health problem and that 80 percent were in favor of the emissions inspection program.

SWAT TEAM OR LIFT-OFF

In late December, we behaved like expectant fathers or like NASA engineers at countdown. Administratively, we got ready. We formed a SWAT team approach. We pulled our facilities inspectors off every other job and scheduled them to visit every inspection station on an educational periodic twice in January and once in February. We had a special team just to visit stations for a repair cost survey to guarantee that the cost of repairs would not get out of hand. Three teams were readied to respond immediately for undercover investigations. Three mobile van referee stations were readied to answer the public's call for a second inspection opinion. We added personnel to central staff to answer questions and complaints from the public. Any complaint would be handled within 24 hours. We teamed up with the contractor's field staff. We wanted every pulse beat. We met with industry association leaders. We sent out administration teams to personally contact all groups that might affect the program such as local consumer boards, public interest groups, libraries, state and local government and enforcement agencies. We talked to garagemen in round robin evening meetings and we dispersed, throughout the area, thousands of pamphlets and consumer bulletins in public places.

We sat on this so tightly in January, we could have run a maximum security prison.

RESULTS

The results have been gratifying. The ship is in orbit. We have inspected 1.2 million vehicles in four months and have received only 39 complaints. We expected four thousand complaints a year. We're failing seven percent or about 21,000 cars a month. Approximately 35 cars have been waived under a waiver program. Far less than expected. (Our waiver clerk is like the Maytag repairman.) Our average cost of repair is now $22.87, but we are continuing to monitor these costs in the stations. Pretesting and pre-repairing is going on extensively and, therefore, masking true failure rates and true repair costs. But this is not unlike the practice in the safety inspection program. Our survey also shows that customers are having their "regular" tune-ups done at the time of inspections. Criticism has been all but nonexistent and, in fact, most of the media has been positive, constructive and informative about the program. Few people have asked for referee vans.

But, the real pizzazz is the computer printout. We record every inspection - both emissions and safety.

The contractor picks up the tapes once a month on his machine calibration day, pools them, and ships them to us.

We spin out management reports showing failure rates by every category.

We spin out what we call enforcement reports identifying those stations doing what we consider to be

excessive transactions
excessive failures overall
excessive brake failures
excessive high pass rates
excessive HC pass rates
excessive CO pass rates
failure by make and model and cylinder
failure by RPM
failure by invalid tests
failure by sticker sequence and so on

- all in all 24 reports - I have some here for those of you who may be interested.

I am happy to report today that New York's massive decentralized garage inspection system is working; it is being regulated and controlled and is serving the public in a highly professional manner.

The future for the New York Program calls for more training opportunities for mechanics to raise their skill level which, in turn, should raise the public's confidence in the repair service. And the public needs more detailed information on the type of emissions repairs necessary to fix their vehicles.

New York is currently evaluating the merits of expanding its system to include heavy-duty trucks and additional measures to control tampering.

The goal of the New York State Emissions Inspection Program for a cleaner, safer, and more fuel efficient vehicle fleet is becoming a reality.

That's the fact in New York.

We had lift-off. All systems go.

We have launched our system and we are in orbit.

But wait!!! - there seems to be an assault on our base station. They are cutting our lifeline. They are going to leave us up here all alone. Out of 30 states, only nine have mandated repair programs. Out of ten Eastern States which share intimately - their dirty air with us - only four have mandated repair programs.

Many states have stopped their launch countdown.

Congress is considering deleting the mandate for I/M.

The President's EPA is considering deleting itself.

I was surprised last week as I'm sure some of you were by EPA's letter to eleven states. I had previously thought that EPA "1982" would not publicly identify with I/M. Back in January - after we had started our program - we asked EPA to give us a letter of congratulations for use in the media and to tell us what a great job we did and were doing.

EPA's response from Washington, D.C., was - where's New York? What's I/M?

I - being quick-witted - began to get an inkling that the game was changing.

It took me five years to accept "mandate." I lived with the mandate for two-and-a-half years beating up every naysayer in New York and now I hear people talking about voluntary.

I say if you don't like "your house is on fire" - would you buy, "if you're not winning, you're losing"?

While it's true that Congress is considering deleting the I/M mandate, there may well be no bill this summer. And, a new Congress is not that far off. So perhaps the real focus should be on how this Administration is going to deal with the law that's still on the books. Will they pick up their responsibility and push the lingering States to move ahead? Will they withhold federal monies? Will the April 30th threat be followed through?

Let me say that, left to their own devices, states cannot correct themselves. Their reward systems are in the short range. Their span of attention is two years.

I suggest that the New Federalism that gives oral support to States' self-reliance looks very much like the old States' Rights cause in a new costume - a new acting role.

I suggest that the Federal Government is and always was the father and the guardian of interstate relations.

In the final analysis -

If politics is an argument about the future - then we are all in this conference - politicians. And, therefore, we must continue those efforts that have repelled the assaults on the Clean Air Act.

In this regard, I invite you to join with New York State and use your congressional delegations in cooperation with the Clean Air Coalition to mandate I/M - for States' Rights cannot address Interstate Problems - States' Rights cannot address Clean Air.

The Colorado I/M Data Collection System

Presented by Rick Barrett

Colorado has developed a unique data collection system as part of their decentralized inspection/maintenance program. This data collection system may be applicable to programs of other designs in other states. Before I go into much detail about the data system I will talk about the I/M Program in Colorado so you have a better understanding.

Colorado's I/M Program is called the "Air Program" which stands for Automobile Inspection and Readjustment Program. It began on July 1, 1981 for vehicles undergoing a change of ownership as well as State and county fleet vehicles and those vehicles registered into the program area for the first time. On January 1, 1982 the program moved into full operation with yearly inspection's required. The inspection area covers the majority of the eight counties which run up and down the front range from Colorado Springs up through Denver and Boulder to Fort Collins. The inspection is performed on 1968 and newer passenger cars and light duty trucks. The program is a decentralized one with the inspection done in privately owned garage. The vehicles which undergo inspection are measured for hydrocarbons and carbon monoxide under a no-load condition. In addition a visual inspection for 1982 and newer vehicles is part of the inspection. This includes the catalytic converter air injection system and leaded fuel inlet restrictor.

There is one other aspect of the program which I had better explain since it closely ties with the data system discussion that will follow. The readjustment aspect of the "Air Program" has to do with what happens to the failed vehicles. The vast majority of vehicles in the program, specifically, the 1968 to 1980 models, receive only a series of adjustments if they fail the inspection. The program is designed to give us the ambient air improvement we need through the use of only these adjustments which are performed on the failed fleet. These adjustments are dwell, timing, idle speed, idle air/fuel ratio and fast idle speed. These adjustments are performed according to manufacturers specifications and amount to a low emissions tune-up without any parts being purchased. After these adjustments are performed another set of emissions readings are taken, to show the tailpipe reductions and the vehicle is issued a window sticker. On 1981 and newer vehicles if these adjustments do not bring the vehicle into compliance the owner must spent at least one hundred dollars or bring it into compliance whichever occurs first.

When Colorado's air pollution staff was considering it's I/M data needs a close look at the program elements which affect the data system was needed. Any other State developing an I/M data system will also need to consider program elements of this type. The elements which affected Colorado's system are items such as the inspection taking place on 1.3 to 1.4 million vehicles per year. The inspection is performed in 1300 licensed garages by approximately 3300 licensed mechanics. The inspection involves curb idle HC and CO levels for 1968 to 1980 vehicles but a curb idle/ 2500 rpm / second curb idle inspection for 1981 and newer vehicles. The fact that only adjustments are required on most vehicles and the visual inspection and one hundred dollar cost requirements on 1981 and newer vehicles all affected the design of our data system. These items will affect the system design and to a degree control how much data will need to be retrieved.

The next step facing our staff was to identify the basic data needs and the methods available for collection of data. Obviously the basic data for program monitoring was necessary. Items such as pass/fail rate, reductions in HC and CO after the required adjustments and the program costs were identified as items which must be collected and analyzed. This information is needed to report the status of the program as a whole.

In addition there was an underlying desire to monitor the "individuals" in the AIR Program. The ability to monitor one particular mechanics or one particular stations performance would be a good quality control feature. The ability to track any one vehicle would also have advantages that might be lost without this desire to track individuals. Considerations of this type will drastically affect the data system design.

The next major task we addressed was the collection options which can be used in a decentralized I/M program. All options were considered. These included everything from a New York style data collecting analyzer all the way to the other extreme of a hand written and manually tabulated system. In between these two extremes are several other interesting options. There are two types of hand written machine readable form systems presently in wide use which interested us. One is called an optical character reader and it actually reads alpha numeric hand written symbols and the other is called a optical mark reader and it reads forms with small dots filled in with a number two pencil. Both of these systems appeared to have potential use in our application.

Sampling considerations and the cost and practicability of the collection options needed to be considered. For our desire to be capable of monitoring the individuals we needed a 100 percent sample. For simple program effectiveness monitoring however, a smaller sample would work. For all of the collection options there were other decisions which needed to be made. Equipment buy/lease considerations had to be weighed. Down-time and back-up equipment considerations were made. A search for contractors who could provide assistance in data collection and/or reduction was conducted. In our review of this we discovered that in Denver many schools use optical scanners and that scanning time could be rented from them. This knowledge made our staff more seriously consider this option.

Lastly the compatability of the collection system with the auto service industry needed to be considered. We had a serious concern as to whether or not the average mechanic could deal with a fill-in-the-dot form concept. After some investigating we discovered that the State of Illinois had used a optical mark sense form in their truck safety program. In addition the mechanics in the State of Colorado who had instruction in emissions control from Colorado State University already had experience with this concept through that training. Investigation into these two systems gave us confidence in this data collection system.

After the Colorado Air Program staff analyzed our needs and our options a decision was made to use an optical mark sense form to capture the data from every inspection in the program. The form used in our I/M program may be seen in Figure 1 at the end of this report. This form is an 8½ x 11" three copy form which requires the front copy to be filed out with a number two pencil. This portion of the form is later separated and scanned to retrieve the data. There are approximately twenty data fields contained on this form. For ease of use, and to serve as a quick reminder, instructions for use of the form have been printed on the back of the third copy.

The data elements which we used on the form are grouped into several categories. The first catagory is vehicle and owner identification information. In this catagory we capture items such as the vehicle identification number, auto make, license plate number, vehicle model year, number of engine cylinders and the owners name and address. The second catagory contains the inspecting conditions. Items of this type include the date of inspection, inspecting station and mechanic number, inspection cost and whether or not an exhaust leak was suspected. The final catagory contains the actual emissions testing information. The first test visual inspection and emissions levels are recorded. If adjustments and a second set of emissions levels are required due to a failure the cost and these tailpipe levels are recorded. If repairs were needed for a 1981 or newer vehicle these costs are also recorded. Lastly, the type of certificate issued for that vehicle is indicated on the data collection form. This data provides us with the basic information we need for both program monitoring and that needed to track each mechanic and each station.

The form collection and input is a fairly straight forward process. The front copy of the form is collected from the inspection station on a periodic basis by State AIR Program personel. These forms are delivered to the contractor where they are scanned on their equipment. This is done on a weekly basis and amounts to approximately 20,000 forms being scanned in one run. Each run is called a batch. The scanner outputs a computer tape which contains everything which was on the original form and two blank spaces. This is called a record. The tape contains one record for each form so that a finished tape will have approximately 20,000 records for each batch. This batch tape is then inputed into a computer accessable to the AIR Program staff.

Once the batch tape has be loaded into our computer another scanning process is conducted. This process looks at each record and does a quality check of how well the mechanic filled out the form. The computer then inserts a code into the blank spots for that record. Each record in the batch will now contain a quality or error code. At this time the computer will generate a batch report. Figure 2 shows a batch report which indicates how many records are in the batch and how many are in the master file. This report also indicates what percentage of "fatal errors" are contained in that batch and the master file. As soon as that information is generated the batch is merged with the master file. This master file now contains records for all vehicles inspected.

The whole intent of this data system is to keep AIR Program staff members up-to-date on program occurances. To fulfill this need a rather elaborate report generation capability is being designed. Much of this capability is in the development stages at this time. For this reason some of the examples shown are design documents only.

On a monthly basis two reports are generated which allow us to look at stations and mechanics from error and performance levels. Figure 3 shows an error report. This report indicates how many form errors are occurring. This information is separated to indicate both the individual station and mechanic's error rate. We use this to provide feedback to mechanics in order to minimize form errors. A similar report called a performance report is also generated by individual station and mechanic. This report indicates how many vehicles were inspected, the pass/fail rate, the emissions reductions achieved by adjustments and the costs. This information is used to track the performance of each mechanic and will show when any one mechanic has a problem. This could be anything from an analyzer malfunction to potential indiscriminate practices by a mechanic. This report is shown in Figure 4.

Other reports are generated on a less frequent basis. A bimonthly report is used to track the current model year performance and to determine pass/fail rates within each standards groupings. Quarterly reports are used to determine vehicle distributions, emissions reductions and overall failure rates. All of this information is used for basic program monitoring.[1]

A very versitile special report capability is inherent in this data system. By computer sorting of the records it is possible to group and monitor all types of vehicles. The ability to do this is based solely on the data fields selected when designing the form. Careful attention to selecting which data is pulled from the master file is essential to meaningful results. The error code which is assigned to each record indicates the severity and location of form coding errors. By eliminating those records from the data analyses the report results can be made error free for those items of interest.

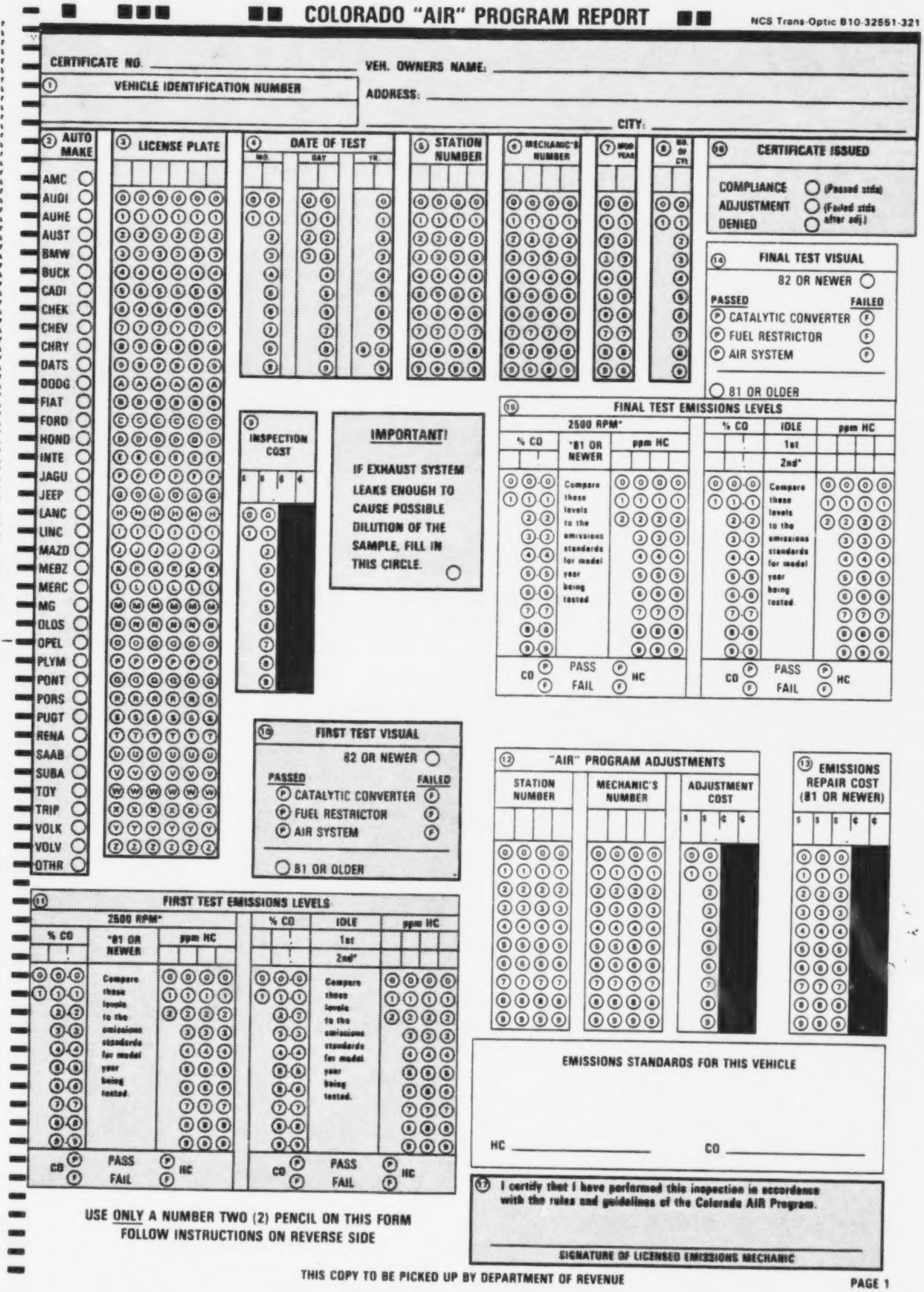
The special reports we have used so far include things such as an analysis of emissions reductions sorted by county. In-use emissions levels by vehicle make can be obtained. We have explored how our program effectiveness would change if we inspected CO emissions only. Perhaps the most illustrative example of the capability of this system can be shown in the following example. By careful selection of vehicle make, model year and engine size we can look at various emission control technology performances. For example, sealed mixture screw vehicles can be compared with non-sealed mixture screw vehicles. Or a comparison of oxidation catalyst to three-way catalyst technologies can be compared. The emissions performance of the 1977 high altitude certified fleet can be compared to other model years. The possibilities of this type of information retrieval are literally limitless.

In conclusion, the Colorado data collection system is a unique approach to monitoring a decentralized I/M program. It can be modified and utilized in other programs of this type. The type of information which can be exacted from the system is limited solely to that which is collected on the form and that which can be derived from it. This report should serve as a brief review of this system. Colorado State University's National Center for vehicle Emissions Control and Safety and the Environmental Protection Agency have prepared a much more detailed report of the Colorado I/M Data Collection System. This report provides the information necessary to develop a program similar to ours and should be obtained should a desire exist to tailor this concept to other I/M programs.

NEWEST INSPECTION FORM

For use beginning July 1, 1982

FIGURE 1A



COLORADO "AIR" PROGRAM REPORT

NCS Trans-Optic 810-32551-321

CERTIFICATE NO. ____________________

VEH. OWNERS NAME: ____________________

① VEHICLE IDENTIFICATION NUMBER

ADDRESS: ____________________

CITY: ____________________

② AUTO MAKE

AMC ○
AUDI ○
AUHE ○
AUST ○
BMW ○
BUCK ○
CADI ○
CHEK ○
CHEV ○
CHRY ○
DATS ○
DODG ○
FIAT ○
FORD ○
HOND ○
INTE ○
JAGU ○
JEEP ○
LANC ○
LINC ○
MAZD ○
MEBZ ○
MERC ○
MG ○
OLDS ○
OPEL ○
PLYM ○
PONT ○
PORS ○
PUGT ○
RENA ○
SAAB ○
SUBA ○
TOY ○
TRIP ○
VOLK ○
VOLV ○
OTHR ○

③ LICENSE PLATE

④ DATE OF TEST — MO. DAY YR.

⑤ STATION NUMBER

⑥ MECHANIC'S NUMBER

⑦ MOD. YEAR

⑧ NO. OF CYL.

⑯ CERTIFICATE ISSUED

COMPLIANCE ○ (Passed stds)
ADJUSTMENT ○ (Failed stds after adj.)
DENIED ○

⑭ FINAL TEST VISUAL

82 OR NEWER ○

PASSED		FAILED
Ⓟ	CATALYTIC CONVERTER	Ⓕ
Ⓟ	FUEL RESTRICTOR	Ⓕ
Ⓟ	AIR SYSTEM	Ⓕ

○ 81 OR OLDER

⑨ INSPECTION COST — $ $ ¢ ¢

IMPORTANT!

IF EXHAUST SYSTEM LEAKS ENOUGH TO CAUSE POSSIBLE DILUTION OF THE SAMPLE, FILL IN THIS CIRCLE. ○

⑮ FINAL TEST EMISSIONS LEVELS

2500 RPM* — % CO — *81 OR NEWER — ppm HC

Compare these levels to the emissions standards for model year being tested.

CO Ⓟ PASS Ⓟ HC
Ⓕ FAIL Ⓕ

IDLE — % CO — 1st — 2nd* — ppm HC

Compare these levels to the emissions standards for model year being tested.

CO Ⓟ PASS Ⓟ HC
Ⓕ FAIL Ⓕ

⑩ FIRST TEST VISUAL

82 OR NEWER ○

PASSED		FAILED
Ⓟ	CATALYTIC CONVERTER	Ⓕ
Ⓟ	FUEL RESTRICTOR	Ⓕ
Ⓟ	AIR SYSTEM	Ⓕ

○ 81 OR OLDER

⑫ "AIR" PROGRAM ADJUSTMENTS

STATION NUMBER — MECHANIC'S NUMBER — ADJUSTMENT COST ($ $ ¢ ¢)

⑬ EMISSIONS REPAIR COST (81 OR NEWER) — $ $ $ ¢ ¢

⑪ FIRST TEST EMISSIONS LEVELS

2500 RPM* — % CO — *81 OR NEWER — ppm HC

Compare these levels to the emissions standards for model year being tested.

CO Ⓟ PASS Ⓟ HC
Ⓕ FAIL Ⓕ

IDLE — % CO — 1st — 2nd* — ppm HC

Compare these levels to the emissions standards for model year being tested.

CO Ⓟ PASS Ⓟ HC
Ⓕ FAIL Ⓕ

EMISSIONS STANDARDS FOR THIS VEHICLE

HC ____________ CO ____________

⑰ I certify that I have performed this inspection in accordance with the rules and guidelines of the Colorado AIR Program.

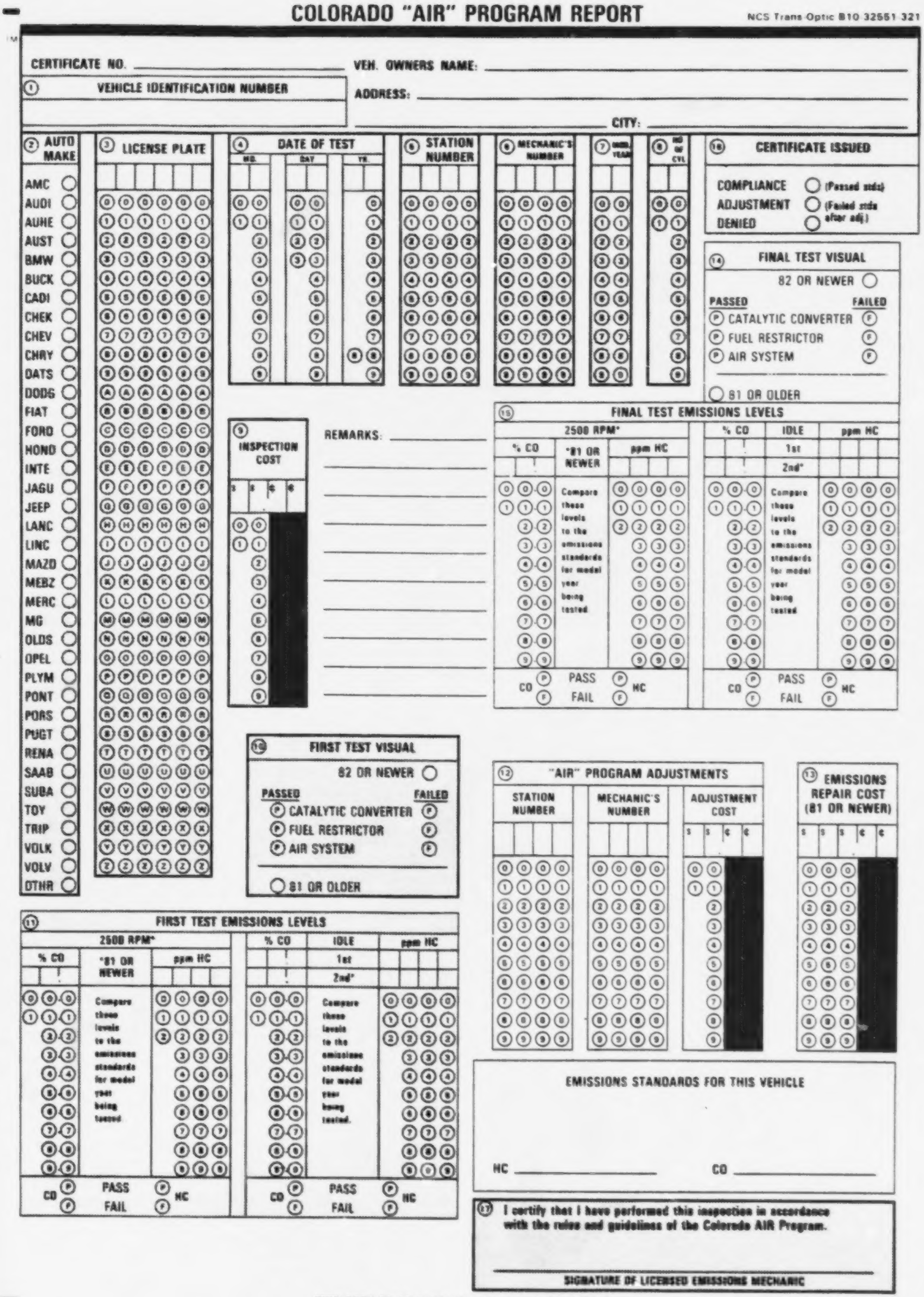
____
SIGNATURE OF LICENSED EMISSIONS MECHANIC

USE ONLY A NUMBER TWO (2) PENCIL ON THIS FORM
FOLLOW INSTRUCTIONS ON REVERSE SIDE

THIS COPY TO BE PICKED UP BY DEPARTMENT OF REVENUE

PAGE 1

FIGURE 1B



COLORADO "AIR" PROGRAM REPORT

NCS Trans-Optic 810 32551 321

CERTIFICATE NO. ______________ VEH. OWNERS NAME: ______________

① VEHICLE IDENTIFICATION NUMBER

ADDRESS: ______________

______________ CITY: ______________

② AUTO MAKE

○ AMC
○ AUDI
○ AUHE
○ AUST
○ BMW
○ BUCK
○ CADI
○ CHEK
○ CHEV
○ CHRY
○ DATS
○ DODG
○ FIAT
○ FORD
○ HOND
○ INTE
○ JAGU
○ JEEP
○ LANC
○ LINC
○ MAZD
○ MEBZ
○ MERC
○ MG
○ OLDS
○ OPEL
○ PLYM
○ PONT
○ PORS
○ PUGT
○ RENA
○ SAAB
○ SUBA
○ TOY
○ TRIP
○ VOLK
○ VOLV
○ OTHR

③ LICENSE PLATE

④ DATE OF TEST — MO. DAY YR.

⑤ STATION NUMBER

⑥ MECHANIC'S NUMBER

⑦ MODEL YEAR

⑧ NO. OF CYL

⑯ CERTIFICATE ISSUED

COMPLIANCE ○ (Passed stds)
ADJUSTMENT ○ (Failed stds after adj.)
DENIED ○

⑭ FINAL TEST VISUAL

82 OR NEWER ○

PASSED / FAILED
Ⓟ CATALYTIC CONVERTER Ⓕ
Ⓟ FUEL RESTRICTOR Ⓕ
Ⓟ AIR SYSTEM Ⓕ

○ 81 OR OLDER

⑨ INSPECTION COST $ $ ¢ ¢

REMARKS: ______________

⑮ FINAL TEST EMISSIONS LEVELS

2500 RPM* — % CO | *81 OR NEWER | ppm HC

Compare these levels to the emissions standards for model year being tested

IDLE — % CO | 1st / 2nd* | ppm HC

Compare these levels to the emissions standards for model year being tested

CO Ⓟ PASS Ⓟ HC
CO Ⓕ FAIL Ⓕ HC

⑩ FIRST TEST VISUAL

82 OR NEWER ○

PASSED / FAILED
Ⓟ CATALYTIC CONVERTER Ⓕ
Ⓟ FUEL RESTRICTOR Ⓕ
Ⓟ AIR SYSTEM Ⓕ

○ 81 OR OLDER

⑫ "AIR" PROGRAM ADJUSTMENTS

STATION NUMBER | MECHANIC'S NUMBER | ADJUSTMENT COST $ $ ¢ ¢

⑬ EMISSIONS REPAIR COST (81 OR NEWER) $ $ $ ¢ ¢

⑪ FIRST TEST EMISSIONS LEVELS

2500 RPM* — % CO | *81 OR NEWER | ppm HC

Compare these levels to the emissions standards for model year being tested

IDLE — % CO | 1st / 2nd* | ppm HC

Compare these levels to the emissions standards for model year being tested.

CO Ⓟ PASS Ⓟ HC
CO Ⓕ FAIL Ⓕ HC

EMISSIONS STANDARDS FOR THIS VEHICLE

HC ______________ CO ______________

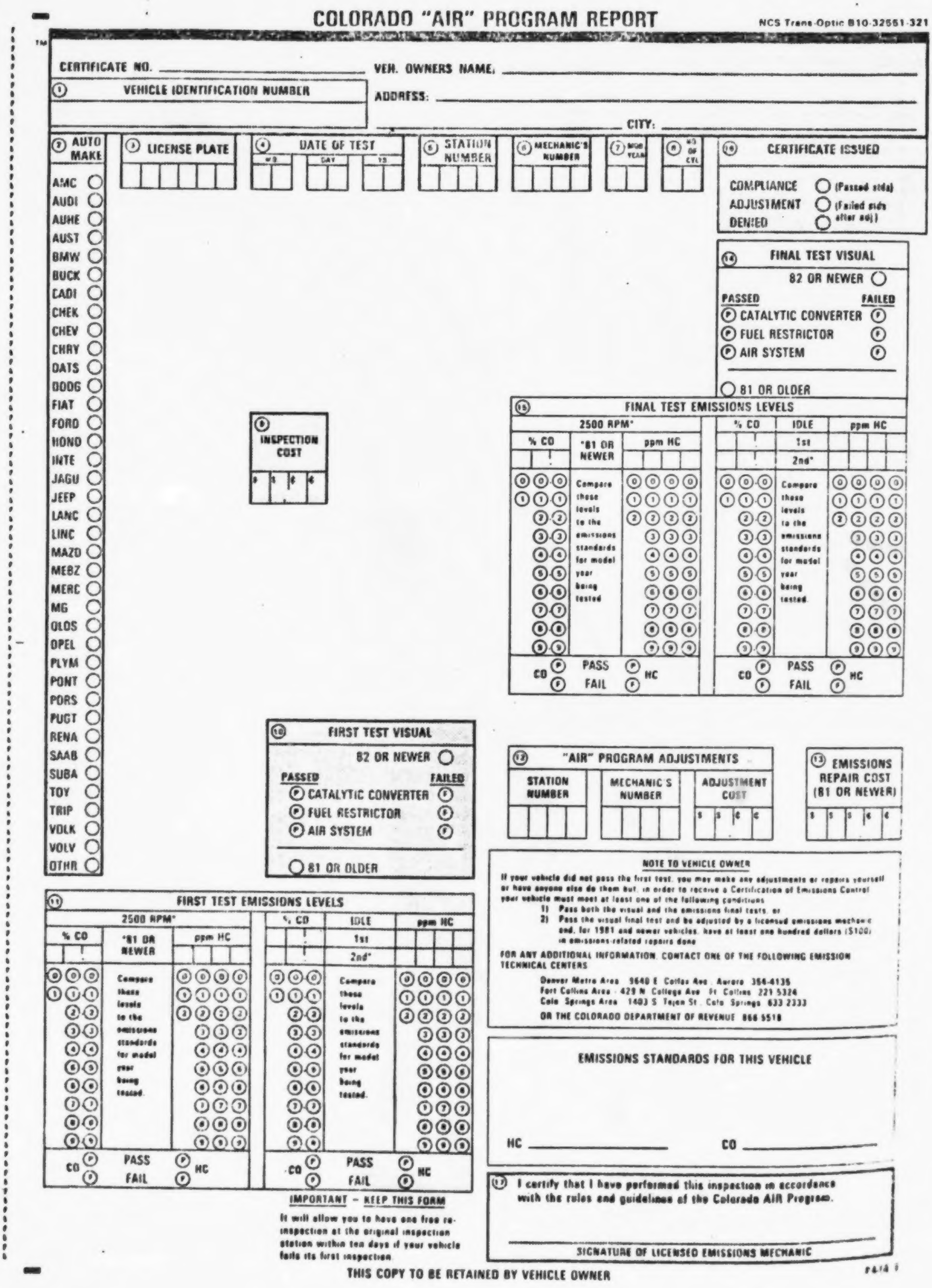
⑰ I certify that I have performed this inspection in accordance with the rules and guidelines of the Colorado AIR Program.

____
SIGNATURE OF LICENSED EMISSIONS MECHANIC

THIS COPY TO BE FILED AT "AIR" PROGRAM STATION

PAGE 2

FIGURE 1C



COLORADO "AIR" PROGRAM REPORT

NCS Trans-Optic B10-32551-321

CERTIFICATE NO. ______________ VEH. OWNERS NAME, ______________

① VEHICLE IDENTIFICATION NUMBER

ADDRESS: ______________

______________ CITY: ______________

② AUTO MAKE

AMC ○
AUDI ○
AUHE ○
AUST ○
BMW ○
BUCK ○
CADI ○
CHEK ○
CHEV ○
CHRY ○
DATS ○
DODG ○
FIAT ○
FORD ○
HOND ○
INTE ○
JAGU ○
JEEP ○
LANC ○
LINC ○
MAZD ○
MEBZ ○
MERC ○
MG ○
OLDS ○
OPEL ○
PLYM ○
PONT ○
PORS ○
PUGT ○
RENA ○
SAAB ○
SUBA ○
TOY ○
TRIP ○
VOLK ○
VOLV ○
OTHR ○

③ LICENSE PLATE

④ DATE OF TEST — MO DAY YR

⑤ STATION NUMBER

⑥ MECHANIC'S NUMBER

⑦ MOD YEAR

⑧ NO OF CYL

⑨ INSPECTION COST — $ $ ¢ ¢

⑲ CERTIFICATE ISSUED

COMPLIANCE ○ (Passed stds)
ADJUSTMENT ○ (Failed stds after adj)
DENIED ○

⑭ FINAL TEST VISUAL

82 OR NEWER ○

PASSED		FAILED
Ⓟ	CATALYTIC CONVERTER	Ⓕ
Ⓟ	FUEL RESTRICTOR	Ⓕ
Ⓟ	AIR SYSTEM	Ⓕ

○ 81 OR OLDER

⑮ FINAL TEST EMISSIONS LEVELS

2500 RPM* — % CO — *81 OR NEWER — ppm HC

% CO — IDLE 1st / 2nd* — ppm HC

Compare these levels to the emissions standards for model year being tested.

⓪⓪.⓪ ①①.① ②.② ③.③ ④.④ ⑤.⑤ ⑥.⑥ ⑦.⑦ ⑧.⑧ ⑨.⑨

⓪⓪⓪⓪ ①①①① ②②②② ③③③ ④④④ ⑤⑤⑤ ⑥⑥⑥ ⑦⑦⑦ ⑧⑧⑧ ⑨⑨⑨

CO Ⓟ PASS Ⓟ HC
Ⓕ FAIL Ⓕ

⑩ FIRST TEST VISUAL

82 OR NEWER ○

PASSED		FAILED
Ⓟ	CATALYTIC CONVERTER	Ⓕ
Ⓟ	FUEL RESTRICTOR	Ⓕ
Ⓟ	AIR SYSTEM	Ⓕ

○ 81 OR OLDER

⑫ "AIR" PROGRAM ADJUSTMENTS

STATION NUMBER — MECHANIC'S NUMBER — ADJUSTMENT COST $ $ ¢ ¢

⑬ EMISSIONS REPAIR COST (81 OR NEWER) — $ $ $ ¢ ¢

⑪ FIRST TEST EMISSIONS LEVELS

2500 RPM* — % CO — *81 OR NEWER — ppm HC

% CO — IDLE 1st / 2nd* — ppm HC

Compare these levels to the emissions standards for model year being tested.

⓪⓪.⓪ ①①.① ②.② ③.③ ④.④ ⑤.⑤ ⑥.⑥ ⑦.⑦ ⑧.⑧ ⑨.⑨

⓪⓪⓪⓪ ①①①① ②②②② ③③③ ④④④ ⑤⑤⑤ ⑥⑥⑥ ⑦⑦⑦ ⑧⑧⑧ ⑨⑨⑨

CO Ⓟ PASS Ⓟ HC
Ⓕ FAIL Ⓕ

NOTE TO VEHICLE OWNER

If your vehicle did not pass the first test, you may make any adjustments or repairs yourself or have anyone else do them but, in order to receive a Certification of Emissions Control your vehicle must meet at least one of the following conditions

1) Pass both the visual and the emissions final tests, or
2) Pass the visual final test and be adjusted by a licensed emissions mechanic and, for 1981 and newer vehicles, have at least one hundred dollars ($100) in emissions-related repairs done

FOR ANY ADDITIONAL INFORMATION, CONTACT ONE OF THE FOLLOWING EMISSION TECHNICAL CENTERS

Denver Metro Area 9640 E Colfax Ave, Aurora 364-4135
Fort Collins Area 429 N College Ave Ft Collins 221 5324
Colo Springs Area 1403 S Tejon St, Colo Springs 633 2333

OR THE COLORADO DEPARTMENT OF REVENUE 866 5518

EMISSIONS STANDARDS FOR THIS VEHICLE

HC ______________ CO ______________

⑰ I certify that I have performed this inspection in accordance with the rules and guidelines of the Colorado AIR Program.

____

SIGNATURE OF LICENSED EMISSIONS MECHANIC

IMPORTANT – KEEP THIS FORM

It will allow you to have one free re-inspection at the original inspection station within ten days if your vehicle fails its first inspection.

THIS COPY TO BE RETAINED BY VEHICLE OWNER

F414 I

FIGURE 1D

INSTRUCTIONS TO LICENSED EMISSIONS MECHANICS

NOTICE: Only a Licensed Emissions Mechanic may perform this inspection.

- Page 1 (top copy) of this form will be scanned electronically.
- Please keep page 1 free of dirt or grease.
- Do NOT fold, staple, spindle, or mutilate page 1.
- Do NOT make ANY marks on page 1 other than specified in directions.
- You may make notes on pages 2 and 3 ONLY.
- Use ONLY a NUMBER TWO pencil on this form.
- Where boxes are provided put one and only one number or letter in each box. If there are more boxes than numbers or letters put enough zeroes in front (to the left) to fill up the extra boxes. For example, if the emission levels are 4.8% CO and 750 ppm HC.

ENTER

% CO			ppm HC			
0	4	. 8	0	7	5	0

DO NOT ENTER

% CO			ppm HC			
4	8	. 0	7	5	0	0

- After the boxes are marked, fill in the circle under each box which has a letter or number that matches the letter or number in the box above. There should be one and only one circle filled in under each box.

FIRST INSPECTION

PRINT - Name and address of vehicle owner at top of this form.

ITEM

① Vehicle Identification Number - Write in VIN number.

② Auto Make - Fill in circle for auto make.

③ License Plate - Enter license plate number and fill in circles (if temporary tag leave blank, if more than six characters use first six).

④ Date of Test - Enter month, day and year and fill in circles.

⑤ Station Number - Enter your station's license number and fill in circles.

⑥ Mechanic's Number - Enter your emissions mechanic's license number, and fill in circles.

⑦ Model Year - Enter last two digits of vehicle's model year and fill in circles (example: 1972 enter 72).

⑧ No. of Cyl. - Enter number of cylinders in engine and fill in circles (if rotary engine enter number of rotors).

⑨ Inspection Cost - Enter cost of inspection in dollars and cents (maximum $10.00) and fill in circles under dollar portion only.

⑩ First Test Visual

1981 AND OLDER VEHICLES: Fill in "81 OR OLDER" circle. (No visual inspection needed.)

1982 AND NEWER VEHICLES: Fill in "82 OR NEWER" circle, complete first visual inspection and fill in a pass or fail circle for each emissions control system.

⑪ First Test Emissions Levels -

1968-1980 VEHICLES: Complete first test emissions inspection, enter readings in 1st IDLE boxes and fill in proper circles below. Compare readings with State emissions standards and fill in pass or fail circles for CO and for HC.

1981 AND NEWER VEHICLES: Complete first test two speed emissions inspection, enter readings in 1st IDLE, 2500 RPM and 2nd IDLE boxes. Fill in the proper circles under 2500 RPM - %CO and ppm HC (left half of block ⑪). From the right half of block ⑪ select the lowest IDLE CO reading of the two idle tests and fill in the proper circles under IDLE %CO. Then select the lowest IDLE HC reading (from either idle test) and fill in the proper circles under IDLE ppm HC. Compare 2500 RPM and IDLE readings marked in the circles with State emissions standards and fill in CO and HC pass or fail circles for each speed. (Vehicles must pass at both 2500 RPM and idle to pass the first test.)

NOTE: THIS COMPLETES FIRST INSPECTION. IF VEHICLE HAS PASSED ALL REQUIREMENTS, FILL IN "COMPLIANCE" CIRCLE IN ITEM ⑯ AND SIGN ITEM ⑰. ENTER CERTIFICATE OF EMISSIONS CONTROL STICKER NUMBER AT TOP OF FORM AND AFFIX STICKER TO THE WINDSHIELD AS SPECIFIED. GIVE PAGE 3 OF REPORT FORM TO VEHICLE OWNER.

VEHICLES FAILING FIRST INSPECTION

ITEM

⑫ "AIR" Program Adjustments - If adjustments were made by a licensed emissions mechanic, enter license numbers of station and mechanic where adjustments were made and cost of adjustments in dollars and cents (maximum $15.00). Fill in circles under station number, mechanic's number and dollar portion of adjustment cost.
NOTE: If adjustments were made by another licensed emissions mechanic, copy this information from "Adjustment Verification Form".

⑬ Emissions Repair Cost - For 1981 and newer vehicles only, enter cost of emissions related repairs in dollars and cents and fill in circles under dollar portion only. Repair costs do not include inspection or initial adjustment fees, or any costs required to pass the visual inspection.

⑭ Final Test Visual -

1981 AND OLDER VEHICLES: Fill in "81 OR OLDER" circle. (No visual inspection needed.)

1982 AND NEWER VEHICLES: Fill in "82 OR NEWER" circle, complete final visual inspection and fill in a pass or fail circle for each emissions control system. (All three systems must be marked "PASSED" in order for a certificate of emissions control to be issued.)

⑮ Final Test Emissions Levels - If adjustments were made by another licensed emissions mechanic, copy data for blocks ⑫ and ⑮ from "Adjustment Verification Form."

1968-1980 VEHICLES: Complete final test emissions inspection, enter readings in 1st IDLE boxes and fill in proper circles below. Compare readings with State emissions standards and fill in pass or fail circles for CO and for HC.

1981 AND NEWER VEHICLES: Complete final test two speed emissions inspection and enter readings and fill in circles as described in item ⑪. Compare readings with State emissions standards and fill in CO and HC pass or fail circles for each speed.

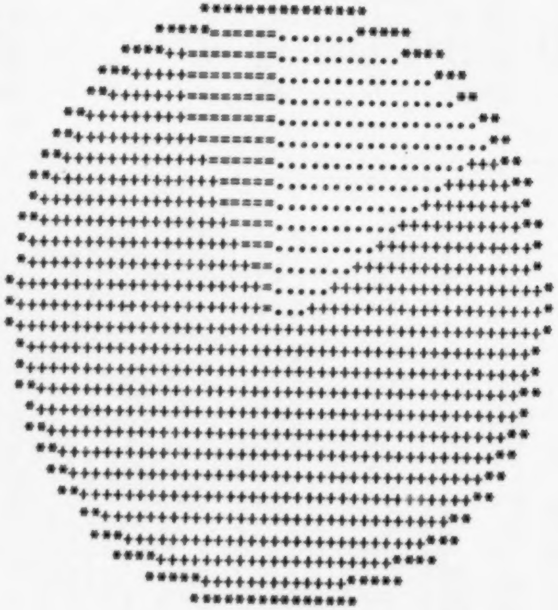
⑯ Certificate Issued - Fill in circle next to:

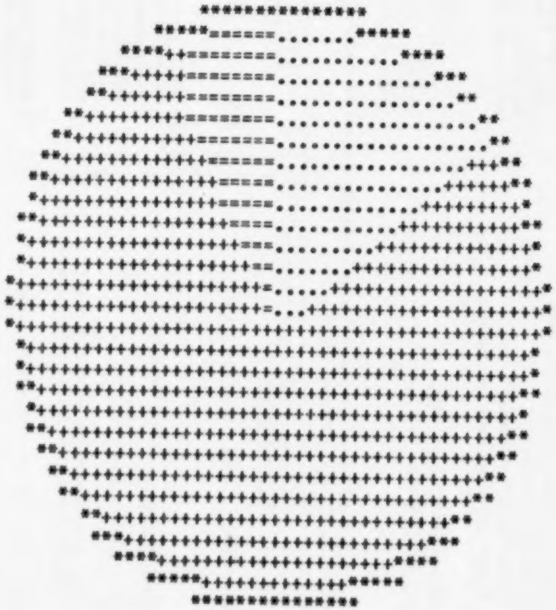
COMPLIANCE	Only if item ⑭ passed and item ⑮ is within State emissions standards.
ADJUSTMENT	Only if item ⑭ passed, item ⑮ failed, adjustments made by a licensed emissions mechanic and, for 1981 and newer vehicles, at least $100 was spent on emissions related repairs.
DENIED	Only if item ⑭ failed or item ⑮ failed and 1) adjustments not made by a licensed emissions mechanic or 2) for 1981 and newer vehicles, less than $100 was spent on emissions repairs.

⑰ Signature of Licensed Emissions Mechanic - After completing this form, sign it, enter number of the sticker issued (or "none" if certification denied) at top of report form and give page 3 to vehicle owner. If a certificate is issued, affix certificate of emissions control sticker to the windshield as specified.

FIGURE 2

```
REPORT DATE                          C O L O R A D O   D E P A R T M E N T   O F   H E A L T H
XXX Z9, 1999                                     INSPECTION/MAINTENANCE PROGRAM
                                                      WEEKLY BATCH SUMMARY

            BATCH TOTALS                                                                     NEW MASTER TOTALS
                                                                                     OLD TOTAL RECORDS
      BEGINNING ID............999999999                                              NEW TOTAL RECORDS.........zzzzzz9
      ENDING ID...............999999999
                                                                                     FORMS WITH NO ERRORS......zzzzzz9
      RECORDS IN................zzzzzz9          FORMS WITH NO ERRORS     :++++
      BAD SCANS.................zzzzzz9          FORMS WITH QUESTIONABLE             FORMS WITH QUESTIONABLE ERRORS
      RECORDS OUT...............zzzzzz9          ERRORS & NO FATAL ERRORS:....       AND NO FATAL ERRORS.......zzzzzz9
                                                 FORMS WITH FATAL ERRORS :====
      FORMS WITH NO ERRORS......zzzzzz9a                                             FORMS WITH FATAL ERRORS...zzzzzz9
      FORMS WITH QUESTIONABLE ERRORS
      AND NO FATAL ERRORS.......zzzzzz9
      FORMS WITH FATAL ERRORS...zzzzzz9
```





```
            FORMS WITH NO ERRORS.........zz9%                          FORMS WITH NO ERRORS.........zz9%
            FORMS WITH QUESTIONABLE ERRORS                             FORMS WITH QUESTIONABLE ERRORS
            AND NO FATAL ERRORS..........zz9%                          AND NO FATAL ERRORS..........zz9%
            FORMS WITH FATAL ERRORS......zz9%                          FORMS WITH FATAL ERRORS......zz9%
```

[a] "Forms with no errors" may be either error free or with errors assigned values lower than the cutpoints specified for this report.

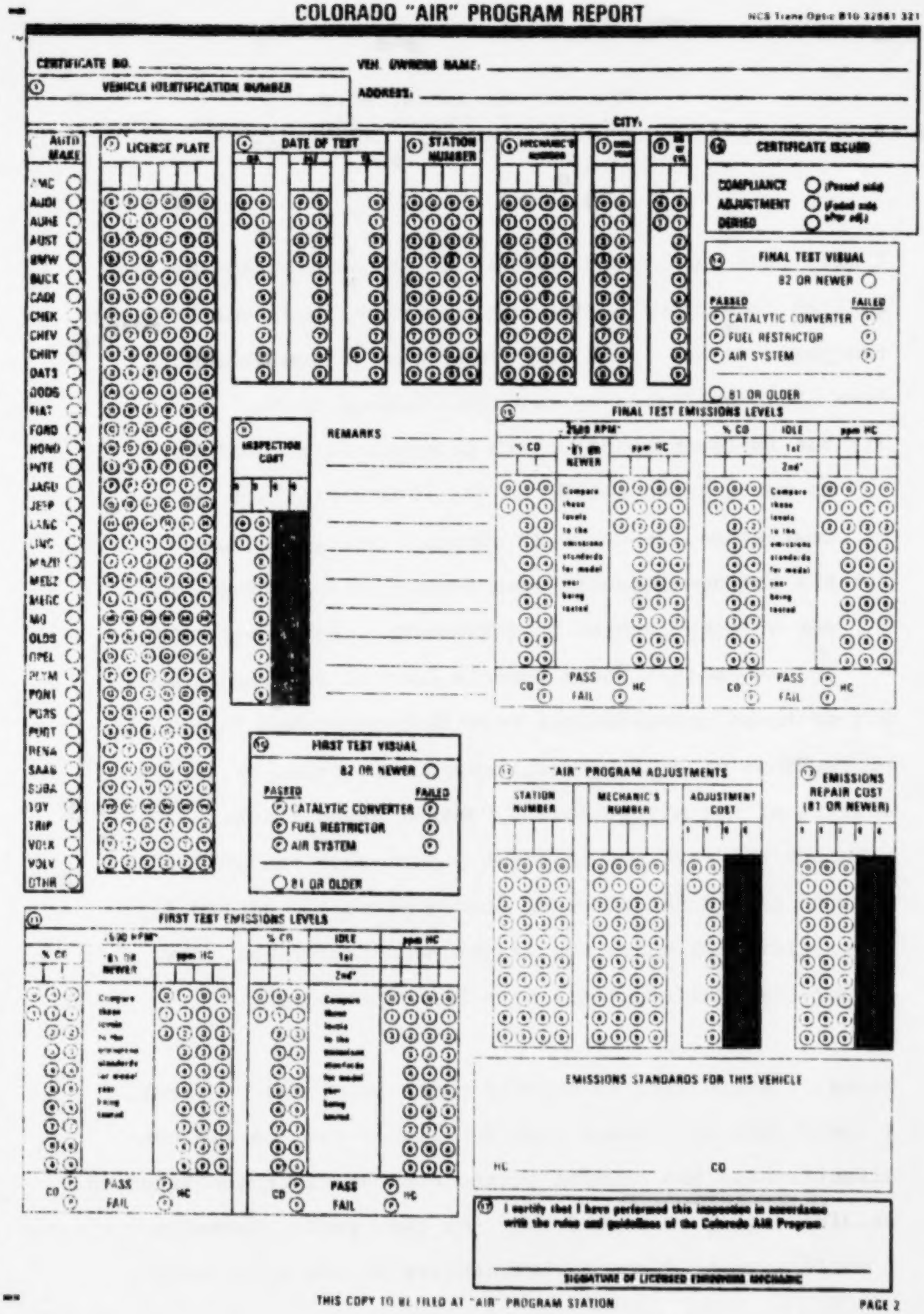
FIGURE 3

```
  BATCH ID RANGE                 C O L O R A D O  D E P A R T M E N T  O F  H E A L T H                               MMM 29, 1999
999999999 - 999999999                            ERROR / PERFORMANCE REPORT                                               PAGE 999
                                                       ERROR SECTION

                          -  -  -  -  -  -  -  -  -  (ALL ERROR RATES EXPRESSED AS PERCENT)  -  -  -  -  -  -  -  -  -  -
                                                      - - - - -INSPECTION  CHECKS- - - - -     - -INSPECTION RESULTS- -   CERT ISSUED
STATION                     ITEM   1,3,4,9,      2,                                                                    DISAGREEMENT
NUMBER        FORMS          NOS: 17,CERT NO.    7,8     10YR,11PF     14YR,15PF      12,13        10PF,11#S    14PF,15#S       16
       MECH    READ   FORM     INSP DATA         VEH    FIRST TEST    FINAL TEST    ADJ/REPAIR    FIRST TEST   FINAL TEST    PASS
       NO.            ERRORS    UNK    ERR       DATA    UNK   ERR     UNK   ERR     UNK   ERR     UNK   ERR    UNK   ERR    /ADJ   OTHR
1000
       0001     999   99.9     99.9   99.9      99.9    99.9  99.9    99.9  99.9    99.9  99.9    99.9  99.9   99.9  99.9    99.9   99.9

       9999     999   99.9     99.9   99.9      99.9    99.9  99.9    99.9  99.9    99.9  99.9    99.9  99.9   99.9  99.9    99.9   99.9

1000   ALL    99999   99.9     99.9   99.9      99.9    99.9  99.9    99.9  99.9    99.9  99.9    99.9  99.9   99.9  99.9    99.9   99.9


1001
       0001     999   99.9     99.9   99.9      99.9    99.9  99.9    99.9  99.9    99.9  99.9    99.9  99.9   99.9  99.9    99.9   99.9

1999   ALL    99999   99.9     99.9   99.9      99.9    99.9  99.9    99.9  99.9    99.9  99.9    99.9  99.9   99.9  99.9    99.9   99.9

1XXX STATUS 999999    99.9     99.9   99.9      99.9    99.9  99.9    99.9  99.9    99.9  99.9    99.9  99.9   99.9  99.9    99.9   99.9

2000
       0001     999   99.9     99.9   99.9      99.9    99.9  99.9    99.9  99.9    99.9  99.9    99.9  99.9   99.9  99.9    99.9   99.9

9998   ALL    99999   99.9     99.9   99.9      99.9    99.9  99.9    99.9  99.9    99.9  99.9    99.9  99.9   99.9  99.9    99.9   99.9

9XXX STATUS 999999    99.9     99.9   99.9      99.9    99.9  99.9    99.9  99.9    99.9  99.9    99.9  99.9   99.9  99.9    99.9   99.9


9999 ?STA#?  99999    99.9     99.9   99.9      99.9    99.9  99.9    99.9  99.9    99.9  99.9    99.9  99.9   99.9  99.9    99.9   99.9


ALL STATUS 9999999    99.9     99.9   99.9      99.9    99.9  99.9    99.9  99.9    99.9  99.9    99.9  99.9   99.9  99.9    99.9   99.9
```

FIGURE 4

```
     BATCH ID RANGE                                                                                             MMM 29, 1999
 999999999 - 999999999                C O L O R A D O  D E P A R T M E N T  O F  H E A L T H                      PAGE 999
                                                ERROR / PERFORMANCE REPORT
                                                   PERFORMANCE SECTION

STATION                ---- CARBON MONOXIDE -----       ----- HYDROCARBONS -----         AVG    LIC ADJMNTS    REQ REPAIRS
NUMBER        FAIL   # OF  AVG EMISSIONS EM REDUCTION  # OF  AVG EMISSIONS EM REDUCTION  INSP   % OF   AVG    % 81+    AVG
       MECH   RATE   VEHS  FIRST FINAL   AVG    %      VEHS  FIRST FINAL   AVG    %      COST   VEHS   COST   VEHS    COST
       NO.
              RET    RTST  RTST  RTST    RTST   RTST   RTST  RTST  RTST    RTST   RTST   ---    RTST   RTST   RTST    81+ R
              ALL    ALL   ALL   ---     ALL    ALL    ALL   ALL   ---     ALL    ALL    ALL    ALL    ALL    ALL     81+ A
1000
       0001   99.9   9999  09.9  09.9    09.9   99.9   9999  09.9  09.9    09.9   99.9   99.9   99.9   99.99  99.9    999.99

       9999   99.9   9999  09.9  09.9    09.9   99.9   9999  09.9  09.9    09.9   99.9   99.9   99.9   99.99  99.9    999.99

1000   ALL    99.9   9999  09.9  09.9    09.9   99.9   9999  09.9  09.9    09.9   99.9   99.9   99.9   99.99  99.9    999.99

1001
       0001   99.9   9999  09.9  09.9    09.9   99.9   9999  09.9  09.9    09.9   99.9   99.9   99.9   99.99  99.9    999.99

1999   ALL    99.9   9999  09.9  09.9    09.9   99.9   9999  09.9  09.9    09.9   99.9   99.9   99.9   99.99  99.9    999.99

1XXX STATUS   99.9   9999  09.9  09.9    09.9   99.9   9999  09.9  09.9    09.9   99.9   99.9   99.9   99.99  99.9    999.99

2000
       0001   99.9   9999  09.9  09.9    09.9   99.9   9999  09.9  09.9    09.9   99.9   99.9   99.9   99.99  99.9    999.99

9998   ALL    99.9   9999  09.9  09.9    09.9   99.9   9999  09.9  09.9    09.9   99.9   99.9   99.9   99.99  99.9    999.99

9XXX STATUS   99.9 999999  09.9  09.9    09.9   99.9 999999  09.9  09.9    09.9   99.9   99.9   99.9   99.99  99.9    999.99

ALL STATUS    99.9 9999999 09.9  09.9    09.9   99.9 9999999 09.9  09.9    09.9   99.9   99.9   99.9   99.99  99.9    999.99
```

FIGURE 1B



COLORADO "AIR" PROGRAM REPORT

NCS Trans Optic B10 32881 321

CERTIFICATE NO. ____________ VEH. OWNERS NAME: ____________

① VEHICLE IDENTIFICATION NUMBER

ADDRESS: ____________

CITY: ____________

AUTO MAKE

AMC ○
AUDI ○
AUHE ○
AUST ○
BMW ○
BUCK ○
CADI ○
CHEK ○
CHEV ○
CHRY ○
DATS ○
DODG ○
FIAT ○
FORD ○
HOND ○
HNTE ○
JAGU ○
JEEP ○
LANC ○
LINC ○
MAZD ○
MERZ ○
MERC ○
MG ○
OLDS ○
OPEL ○
PLYM ○
PONT ○
PORS ○
PUGT ○
RENA ○
SAAB ○
SUBA ○
TOY ○
TRIP ○
VOLK ○
VOLV ○
OTHR ○

LICENSE PLATE

DATE OF TEST

STATION NUMBER

MECHANIC'S NUMBER

CERTIFICATE ISSUED

COMPLIANCE ○ (Passed side)
ADJUSTMENT ○ (Failed side after adj.)
DENIED ○

⑭ FINAL TEST VISUAL

82 OR NEWER ○

PASSED		FAILED
Ⓟ	CATALYTIC CONVERTER	Ⓕ
Ⓟ	FUEL RESTRICTOR	Ⓕ
Ⓟ	AIR SYSTEM	Ⓕ

○ 81 OR OLDER

INSPECTION COST

REMARKS ____________

FINAL TEST EMISSIONS LEVELS

2500 RPM*: % CO; *81 OR NEWER; ppm HC — Compare these levels to the emissions standards for model year being tested

% CO; IDLE 1st / 2nd*; ppm HC — Compare these levels to the emissions standards for model year being tested

CO Ⓟ PASS Ⓟ HC
Ⓕ FAIL Ⓕ

CO Ⓟ PASS Ⓟ HC
Ⓕ FAIL Ⓕ

FIRST TEST VISUAL

82 OR NEWER ○

PASSED		FAILED
Ⓟ	CATALYTIC CONVERTER	Ⓕ
Ⓟ	FUEL RESTRICTOR	Ⓕ
Ⓟ	AIR SYSTEM	Ⓕ

○ 81 OR OLDER

⑪ FIRST TEST EMISSIONS LEVELS

2500 RPM*: % CO; *81 OR NEWER; ppm HC — Compare these levels to the emissions standards for model year being tested

% CO; IDLE 1st / 2nd*; ppm HC — Compare these levels to the emissions standards for model year being tested

CO Ⓟ PASS Ⓟ HC
Ⓕ FAIL Ⓕ

CO Ⓟ PASS Ⓟ HC
Ⓕ FAIL Ⓕ

"AIR" PROGRAM ADJUSTMENTS

STATION NUMBER | MECHANIC'S NUMBER | ADJUSTMENT COST

EMISSIONS REPAIR COST (81 OR NEWER)

EMISSIONS STANDARDS FOR THIS VEHICLE

HC ____________ CO ____________

I certify that I have performed this inspection in accordance with the rules and guidelines of the Colorado AIR Program

SIGNATURE OF LICENSED EMISSIONS MECHANIC

THIS COPY TO BE FILED AT "AIR" PROGRAM STATION

PAGE 2

THE NEED FOR A NEW I/M RATIONALE

By: Kay H. Jones, Ph.D.
Roy F. Weston, Inc.
West Chester, PA 19380

I have been an invited speaker on the subject of the air quality aspects of I/M on numerous occasions over the past two years or so. Each and every time I have presented data which confirmed my earlier findings that:

(1) the implementation of I/M programs which conform to current EPA policy in the 1980's will not be cost-effective CO or HC control strategies, and

(2) EPA has consistently been overly conservative, if not somewhat remiss in forecasting the effectiveness of the Federal Motor Vehicle Control Program (FMVCP).

All of these presentations have been published in the proceedings of conferences, contract reports, or in the Journal of the Air Pollution Control Association.(1)(2)(3)(4) Although the findings in these papers have caused a good deal of consternation among strong advocates of I/M (in particular, EPA under the Carter Administration), few, if any, factual rebuttals have been forthcoming.

Today, I would like to briefly cover two topics. First, I would like to present some additional data on I/M non-effectiveness and control system non-deterioration based on studies I have conducted over the past year. Secondly, I would like to discuss alternatives to I/M which will meet the intent of the Clean Air Act even if it is not amended this year.

In a recent study (5) for the Colorado State Health Department's Division of Air Pollution Control, WESTON was asked to review the I/M air quality effectiveness study conducted by EPA in Portland, Oregon. (6) Although EPA claimed the study clearly showed that significant I/M CO benefits were observed, our review found this not to be the case. Although we concluded that the time series model developed by Taio was appropriate, the necessary data based was not available to exercise it. Only one monitoring site in five in Portland showed a positive result. Additionally, the benefit at this site could only be explained by including the unquantified benefit of extensive traffic pattern modifications adjacent to this site. In our view, any reference to this study should be qualified accordingly. As a result of this review, a much more detailed data acquisition protocol was proposed by WESTON for implementation in Colorado if an ambient benefits program is to be instituted there.

My previous papers have shown that the maximum ozone air quality benefit of a full blown I/M program, if instituted in cities with ozone problems, amounts to, at most, a fraction of a day in terms of probable exceedances of the NAAQS in 1987. The air quality analysis contained in the draft 1982 Transportation Control Plan for Philadelphia (7),

which was released for public comment in April, provided further confirmation of these previous findings. As is the case with most state implementation planning documents, they only reported emissions control requirements and the future emissions residuals associated with various levels of control. Air quality residuals are never discussed. Table 1 shows the forecasts for the Philadelphia SIP based on air quality considerations. Although the planning document suggests that I/M is essential and TCM's are needed to reduce the expected 8% 1987 shortfall in emission control, the air quality residuals analysis clearly does not support such conclusions from a public health perspective. Although this paper is not a treatise on ozone modeling, there is an emerging consensus that the EKMA model specified in EPA's 1982 SIP guidance document is not representative of the real world, present or future. A WESTON study for the Texas Air Control Board (TACB)(8) recommended an alternative model (CBM III) which justified a higher HC control effectiveness in terms of ozone reductions than that predicted by EKMA. The difference was about a 10% benefit. This same difference is more than likely applicable to the Philadelphia situation as well as other major cities. This correction plus the additional credit we identified in Mobile II (ala Mobile IIa) would eliminate the "dreaded" 8% shortfall as well as the need for I/M and TCM's.
I believe that if policy makers at all levels of government were given the opportunity to review the proposed 1982 SIP's

TABLE 1

AIR QUALITY RESIDUALS
AT THE PHILADELPHIA AQCR SIP
MONITORING SITE VS EMISSIONS CONTROL LEVELS(1)

	Scenario	HC Control (%)	O_3(2)	Expected Exceedances (Days)
I.	Base Case	0	0	20.4
II.	FMVCP & RACT	33.0	22.0	1.9
III.	II + I/M	36.0	24.1	1.66
IV.	III + 33 TCM's	36.25	24.3	1.64
V.	IV + shortfall	44.0	29.4	1.00

(1) Worst case site chosen is located in Trenton, New Jersey.

(2) Assumes EKMA is linear over the range of HC controls being analyzed.

from an air quality perspective, I doubt that we would be in the dire political dilemma we are now in with respect to I/M and many other ineffective, costly and economically disruptive regulatory measures which were promulgated by the previous EPA administration.

In addition to our assessment of the EKMA ozone model, the Texas Air Control Board also asked WESTON to examine the Mobile II emissions forecasting model to determine its accuracy and sensitivity to its input assumptions.(9) We were also asked to examine other alternatives to I/M which could further reduce in-use emissions in a cost-effective manner. WESTON concluded that the Mobile II model was probably overestimating the composite 1987 LDV total HC emissions by as much as 29 to 37%. The median reduction was 31.5%. About half of this error was attributable to the fact that methane credit was not being emphasized by EPA and, therefore, many SIP's were being prepared which contained a total hydrocarbon mobile source inventory. The remaining differences were attributable to:

- overstatement of potential deterioration of post-1980 technology, in light of more recent surveillance data
- overstatement of the potential misfueling failure mode between now and 1987 and beyond,

- averaging of 1975 to 1979 model year deterioration rates, as well as assuming linear deterioration.

These results are summarized in Figure 1. These new estimates have a significant bearing on the SIP's currently under review in most states. A 15% overestimate in Mobile II (assuming methane credit has now been taken) translates into a reduced HC control requirement of 5 to 8% for most cities with an ozone problem. This is just about the shortfall which is being identified in the 1982 draft SIP's for most cities with ozone problems, e.g. Phildelphia, Baltimore, Washington, D.C., etc.

Over the past several months, EPA has been modifying Mobile II inasmuch as a Mobile IIa version is apparently now available. I have noted two apparent changes:

1. The default travel fraction subroutine has been modified to reflect a slower turnover to newer cars coupled with lower per vehicle annual VMT.

2. The deterioration rates of post-1979 LDV's have been reduced commensurate with the availability of more recent field surveillance test data (which WESTON used in its TACB study).

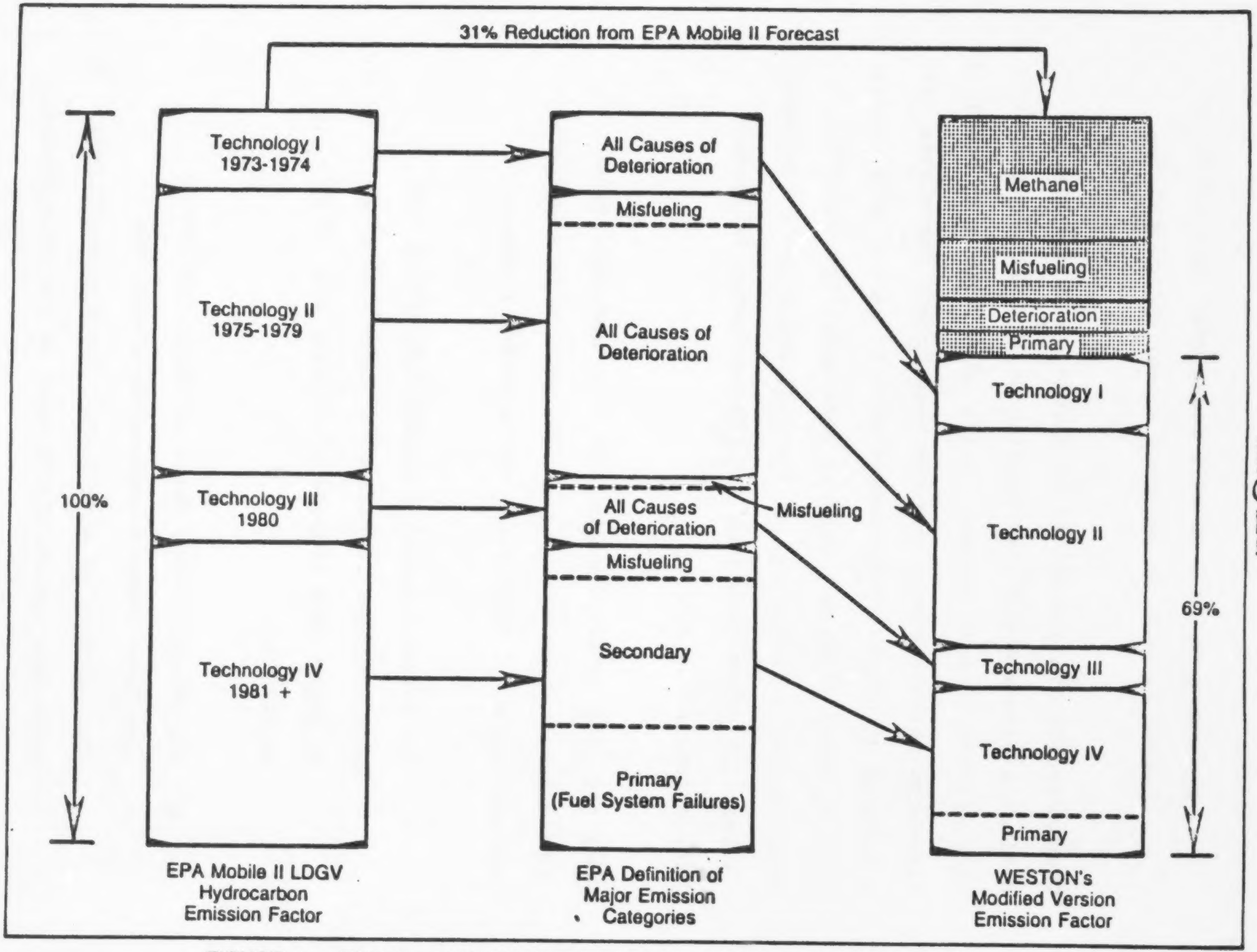

31% Reduction from EPA Mobile II Forecast
100%
Technology I
1973-1974
Technology II
1975-1979
Technology III
1980
Technology IV
1981 +
EPA Mobile II LDGV
Hydrocarbon
Emission Factor
All Causes of
Deterioration
Misfueling
All Causes of
Deterioration
All Causes
of Deterioration
Misfueling
Secondary
Primary
(Fuel System Failures)
EPA Definition of
Major Emission
Categories
Misfueling
Methane
Misfueling
Deterioration
Primary
Technology I
Technology II
Technology III
Technology IV
Primary
WESTON's
Modified Version
Emission Factor
69%

FIGURE 1 THE 1987 LIGHT DUTY GASOLINE VEHICLE HYDROCARBON EMISSION FACTOR AS FORECASTED BY EPA MOBILE II AND WESTON'S MODIFIED VERSION

Table 2 shows the effects of these apparent changes relative to our TACB study results. Except for the primary failure mode contribution of post-1980 cars, there is a constant backward shift in the distribution of emissions contributions by technology type.* However, the new Mobile IIa primary failure mode contribution can only be generated by using some combination of a 0-mile failure rate and an annualized deterioration rate which approximates the 0% at 0 miles and 2% per year annual rate we identified in our TACB study. The small remaining difference is proabably due to a downward adjustment in the Tech III deterioration rates which we did not modify in our study. Hence, there is apparent conformity with respect to modified deterioration rates between the WESTON study and EPA's more recent thinking on Mobile IIa.

I cannot help but point out an apparent fortuitous outcome between the composite forecasts of Mobile II and IIa. Note that the 1987 composite factors are equal to three significant figures, i.e. 2.60 gpm. The probability of such an outcome is extremely low if you consider that there are 20 vehicle age distribution inputs, 20 VMT/model year inputs, and at least four technology/deterioration modes. All three sets of these data are derived from three independent data sources, or at least they should be. I might add that the default Mobile I 1987 composite emissions factor was also 2.60 gpm!

---

*It should be noted that in the Houston case, the travel fraction used in their SIP showed just exactly the opposite trend because of the high regional growth projections.

TABLE II

COMPARISON OF MOBILE II AND IIa 1987 COMPOSITE EMISSIONS FACTORS BY TECHNOLOGY TYPE

	EMISSIONS FACTORS BY TECHNOLOGY TYPE		
TECHNOLOGY TYPE	TACB Base Case	TACB Adjusted(1)	Mobile IIa
I	0.27	---	.385
II	1.02	---	1.156
III	0.21	---	.227
IV sec. + msf. + ox. cat.	0.68	.597	.582
primary	0.42	.371(.267)(2)	.253
	2.60		2.603

(1) adjusted for backward shift in travel fraction

(2) adjusted to 0%, 0 miles and 2%/year deterioration rates.

With these considerations in mind, what logical alternatives are open to those states which have not yet physically implemented programs or who may wish to greatly reduce their current governmental and public costs and still meet the CAA requirements as we now know them? Despite what the previous administration's I/M policy was, the legislative history does not support the programs which were imposed in the 1979 SIP's nor those which are being imposed as part of the 1982 SIP's in many states. Specifically, I refer you to Report No. 95-127 which is the official report of the Senate Committee on Environment and Public Works on S 252, CAA of 1977.(10) Some specific and important quotes are:

1. "At the discretion of the state, an I/M program may include pre-sale inspection, inspection at resale, or inspection only in areas where standards are not being attained."

2. "Whether a measure is reasonable also depends on the level of control to be obtained compared to the economic or social cost."

3. "It should be emphasized that this bill does not define reasonable measures.

State and local officials, in cooperation with EPA must do this in order to preserve maximum flexibility to take into varying local and regional conditions."

4. "The Administrator's authority with respect to measures contained in plans submitted by the States is limited to requiring additional or more stringent measures he deems reasonable where such measures were not included by the State."

As I read this report and other supporting committee dialogue, the current policy is inconsistent with the law. I/M programs are required for extensions beyond 1982. Annual 100% inspections are not required nor are they reasonable unless the State and local agencies agree that they are. Lastly, the program should be tailored to local needs in terms of level of control and economic and social costs.

Our TACB study could not identify a very large emission target for alternative light duty vehicle emission reduction strategies if our contention about the errors in Mobile II prove to be correct. The additional benefits we could identify fell in the range of about 2 to 11% below the mean WESTON 1987 LDV composite factor of 1.78 gpm. When one considers the practical aspects of implementing a partial or 100% I/M program, many, if not most, pre-program implementation date cars will more than likely have to be grandfathered out of the program unless a State already had an anti-tampering statute in place. Further analysis of EPA's 1980/1981 model year surveillance data suggests that deterioration is very low at least within the accumulated mileage range of the available data (see Figure 2). Conversely, this same low mileage data does not support the need for a 100% inspection program. It seems to me that those states that are projecting marginal ozone attainment in 1987 may want some insurance that the FMVCP will indeed meet their expectations. Some states may also find that some form of Inspection or Inspection/Maintenance may be more cost-effective than some additional increment of stationary source control. I believe that some form of change of ownership program, a good public relations program, and adequate mechanics training can meet such air quality needs, as well as satisfy the intent of the current CAA or subsequent amendments.

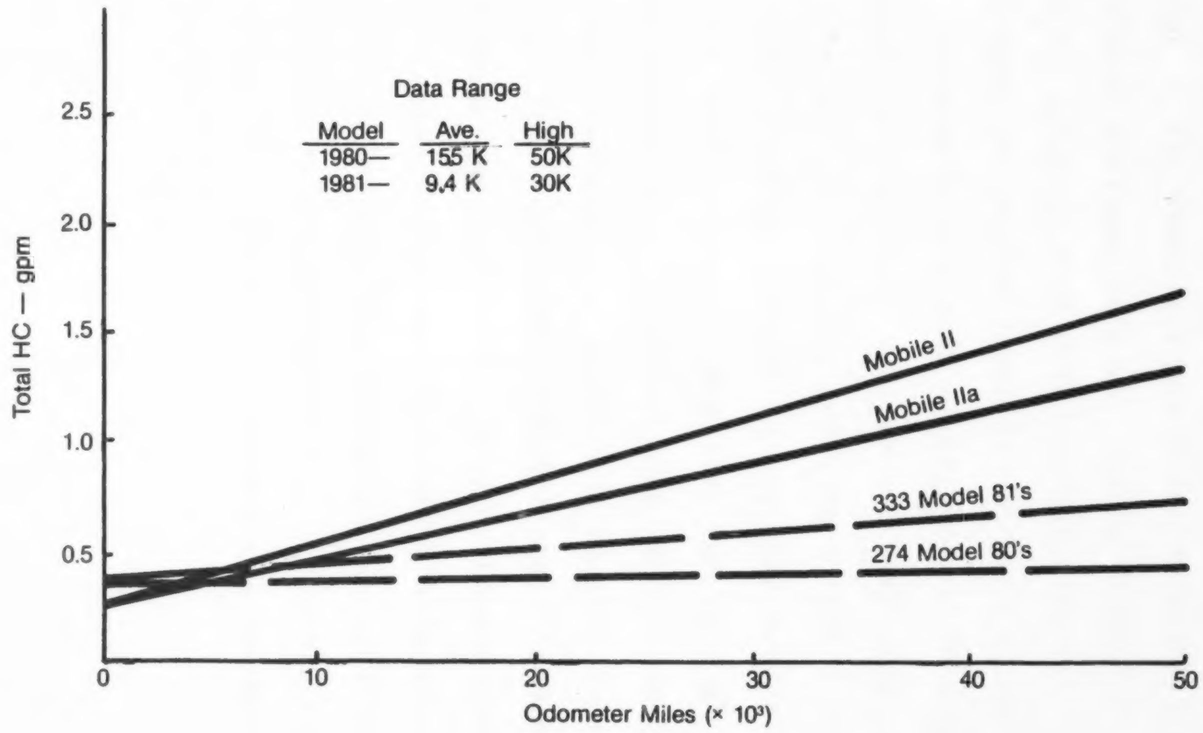


FIGURE 2 EPA FIELD SURVEILLANCE DATA FOR MODEL YEAR 80 & 81 CARS VERSUS MOBILE II & IIa FORECASTS

REFERENCES

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(4) "The Air Quality Benefits of TCM's Including Vehicle I/M", Conference on Local Action for Achieving Growth and Clean Air, Chicago Economic Development Commission Conference, Chicago, March 1982.

(5) "A Conceptual Design of the Colorado CO Benefit Study for the Colorado Department of Health, Air Pollution Control Division", February 1982.

(6) "Statistical Analysis of the Effect of I/M on CO Air Quality in Portland, Oregon", Taio et al, University of Wisconsin for EPA, No. 460/3-81-016, May 1981.

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(9) "Evaluation of Mobile II Emission Factor Model and Alternatives to Further Reduce In Use Emissions", Report by Roy F. Weston, Inc. for the Texas Air Control Board, November 1981.

(10) "Clean Air Act Amendments", Report of the Committee on Environment and Public Works, United States Senate No. 95-127, U.S. Government Printing Office, May 10, 1977.

"IT SHOULD BE EMPHASIZED THAT THIS BILL DOES NOT DEFINE REASONABLE MEASURES. STATE AND LOCAL OFFICIALS, IN COOPERATION WITH EPA MUST DO THIS IN ORDER TO PRESERVE MAXIMUM FLEXIBILITY TO TAKE INTO VARYING LOCAL AND REGIONAL CONDITIONS."

"THE ADMINISTRATOR'S AUTHORITY WITH RESPECT TO MEASURES CONTAINED IN PLANS SUBMITTED BY THE STATES IS LIMITED TO REQUIRING ADDITIONAL OR MORE STRINGENT MEASURES HE DEEMS REASONABLE WHERE SUCH MEASURES WERE NOT INCLUDED BY THE STATE."

"AT THE DISCRETION OF THE STATE, AN I/M PROGRAM MAY INCLUDE PRE-SALE INSPECTION, INSPECTION AT RESALE, OR INSPECTION ONLY IN AREAS WHERE STANDARDS ARE NOT BEING ATTAINED."

"WHETHER A MEASURE IS REASONABLE ALSO DEPENDS ON THE LEVEL OF CONTROL TO BE OBTAINED COMPARED TO THE ECONOMIC OR SOCIAL COST."

Feasibility of Using On-Board Diagnostics for I/M

Presented at
Ninth Annual North American
Motor Vehicle Emissions
Control Conference

Ramada Valley Ho
Scottsdale, Arizona

May 7, 1982

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Environmental Activities Staff
General Motors Corporation

Feasibility of Using On-Board Diagnostics for I/M

Introduction

General Motors (GM) would like to express its appreciation for the opportunity to participate in this Ninth Annual North American Motor Vehicle Emissions Control Conference. GM supports the effort of the States, as well as other institutions in the public and private sectors, to develop rational strategies and viable alternatives to solve air pollution problems.

At the last conference in Atlantic City, our Computer Command Control (CCC) system was discussed and the diagnostic features of the system were demonstrated. Perhaps, by now, you have had a chance to personally experience the system on our 1981 or 1982 model year passenger cars.

Today, I would like to continue the discussion of GM's CCC system by (1) briefly reviewing the basic features of this technology, particularly the on-board diagnostics; (2) summarizing the findings of a Field Service Support Program to determine reasons for customer initiated service incidents; (3) comparing this on-board diagnostic approach to an idle test approach; and (4) assessing the feasibility of implementing an inspection/maintenance (I/M) program using on-board diagnostics.

System Description

In order to achieve the degree of emission control necessary to meet applicable emission standards and fuel economy goals while still maintaining good driveability, GM introduced its CCC system. A variation of this system was first used on some models in California starting in 1978. The system was progressively improved and usage expanded from California to Federal vehicles. By 1981, the CCC system was used on virtually all GM gasoline-powered passenger cars.

As its name implies, the heart of the system is a solid-state microprocessor—an on-board computer. The computer known as the Electronic Control Module (ECM), receives inputs from sensors which monitor oxygen in the exhaust, engine speed, coolant temperature, throttle setting, and engine load (manifold vacuum). Using information received from these sensors, the ECM controls an electronic fuel metering system, either a electro-mechanical carburetor, or fuel injection. Major components of the CCC system are shown in Figure 1.

Having the ability to make thousands of calculations a second, the computer causes the air/fuel ratio to be adjusted approximately 10 times per second to maintain a stoichiometric air/fuel ratio. This enables a 3-way catalytic converter to most effectively reduce emissions of the three regulated pollutants. The principal of operation of a 3-way catalyst is shown in Figure 2.

Since the emission control system differs considerably from systems used in the past and responds differently to malfunctions, General Motors incorporated a self-diagnostic feature to diagnose malfunctions which might occur within the system. Problems can be found and repaired more easily and more quickly than before. This diagnostic feature is used by the assembly plant during assembly of vehicles and by service facilities when the vehicles are in customer service. Although the diagnostic system does not detect all malfunctions which can occur in a vehicles' emission control system, it does detect the majority of malfunctions which can occur within the electronics utilized to control the various emission control system components.

When a problem occurs within a CCC system circuit, the self-diagnostics turns on a "Check Engine Light" on the instrument panel (see Figure 3) and stores a "trouble code" in the memory of the microprocessor. The illuminated light indicates to the vehicle operator that a malfunction has occurred within the CCC system. The circuit involved with the malfunction can be determined simply by grounding a test lead from the ECM which causes the Check Engine Light to blink (or flash) a two-digit code somewhat like Morse Code.

To see how this is done, let's look at code 12. To indicate this code, the light flashes once, followed by a short pause, then it flashes twice in quick succession, followed by a longer pause. It repeats this code 12 three times, then flashes another code if there are more codes stored. Refer to Figure 4 for an illustration of code 12. Some sample trouble codes and their corresponding malfunctions are shown in Figure 5.

It is important to remember, the trouble codes do not give the final answers. They only indicate which circuits to check. The mechanic still must follow steps to determine the exact nature of the problem. But from the inspection viewpoint of an I/M program, the presence of an illuminated Check Engine Light indicates a malfunction within the CCC system which therefore requires additional consideration and possibly some form of maintenance.

Field Service Support Program

General Motors has found that the presence of the Check Engine Light (CEL) has triggered customers' attention and is resulting in vehicles in the field receiving corrective maintenance directly attributable to the CEL.

General Motors has a Field Service Support Program directly concerned with the Computer Command Control system. It is believed that such a program was necessary because of the complexity of the CCC system, the large scale application of the system on a nationwide basis, the on-going commitment by GM to meet applicable standards and regulations, and the realization that customer service often identifies operating modes and conditions not dealt with in developmental testing.

In 1981, the GM Field Service Support Program utilized nine service specialists to report the engine performance problems from twenty-seven select dealerships across the country. Each specialist routinely conducted a review of the repairs made for engine performance problems. In an analysis of over 2,500 reports on

1981 CCC system vehicles, it was determined that 42% of the service incidents were prompted by the Check Engine Light only without an associated driveability complaint. Another 9% of the service incidents were caused by a combined Check Engine Light and a driveability complaint. The remaining 49% of the service incidents resulted from some form of owner complaint. These results are shown in Figure 6.

Obviously, manufacturers do not look forward to any product being returned for service as a result of customer dissatisfaction, but the fact that 42% of those vehicles returned did so solely because of the self-diagnostic system is encouraging to General Motors. Without the CEL, these vehicles may not have received early maintenance and could possibly have remained operating at a lower level of efficiency and a higher emissions rate than intended by the system design.

When considering I/M programs conducted by traditional methods (i.e.: on an annual basis, underhood inspection, tailpipe sample of emissions at some steady state condition) the results of the Field Service Support Program reveal some extremely positive benefits. The utilization of the CEL by customers and the fact that emission related defects are covered by manufacturers' warranty for the useful life of the vehicle (5 yrs/50,000 miles) results in an effective on-going I/M program which correctly identifies emission control system problems as they occur. Contrast this to the traditional yearly inspection typified by customer lines at inspection stations, underhood inspections of vastly different and complex emission control systems, and questionable steady state tailpipe emission samples.

Evaluation of a Diagnostic Approach to I/M

In order to assess the feasibility and effectiveness of using on-board diagnostics, results from EPA in-use vehicle surveillance programs were analyzed. The analysis was limited to 1981 model year GM cars. The 1981 model year was the first year where almost all GM cars sold both in California and the other 49 states were equipped with the CCC system and on-board diagnostics.

As of March 15, 1982, data were available on 255 customer-owned 1981 GM cars. The vehicles averaged approximately 8000 miles and were tested at three (3) test facilities: EPA contractors' laboratories in Los Angeles, San Antonio and Portland. Federal Test Procedure (FTP) and short test data were obtained on these cars in the as-received condition and also after repair. Other data obtained were the repair information for each vehicle and whether or not the Check Engine Light was "on."

The data were analyzed to determine the effectiveness of two indicators (the Check Engine Light and the idle test) which might be used as an I/M approach to identify vehicles requiring maintenance.

The EPA has used the percent of excess emissions identified by a short test as a demonstration of the effectiveness of an I/M test. Percent excess emissions is calculated by determining the percentage of a fleet's FTP emissions in excess of the applicable new vehicle certification standards which are contributed by those vehicles identified by a given I/M test. But, as can be easily demonstrated, a single vehicle which is a gross emitter (i.e.: emitting many times more than the FTP standards) can have a disproportionate and misleading effect on an analysis used to judge the effectiveness of one I/M approach versus another.

General Motors prefers to use fleet average emissions and the reduction in fleet average emissions resulting from vehicles identified by an I/M inspection as a judge of I/M effectiveness. Fleet average emissions compared to the FTP certification standards is the only meaningful method of assessing the in-use performance of vehicles compared to their design intent. Furthermore, fleet average emissions is what affects ambient air quality.

Figures 7 and 8 are HC and CO plots of FTP versus idle test results from the EPA programs for vehicles in the as-received condition. Figures 9 and 10 are the same plots but show the vehicles identified by the idle test (using 207(b) idle test standards of 220 ppm HC and 1.2% CO) and by the Check Engine Light. It is interesting to note that only one vehicle was identified by both approaches. Both tests failed to identify vehicles failing FTP standards. The Check Engine Light approach identified some vehicles which passed FTP emission standards but still required CCC system maintenance.

Test Results - Of the 255 GM vehicles tested, the Check Engine Light identified five vehicles and five vehicles failed to pass the 207(b) idle test standards of 220 ppm HC and 1.2% CO. Only one vehicle was identified by both the CEL and the idle test. The fleet average emission levels of the vehicles as received and the effect on the average emission levels after maintenance was performed on the identified vehicles is shown in Table 1. The reductions in the fleet average emission levels are shown in Table 2.

Table 1
Fleet Average Emission Levels
(grams/mile)
255 Vehicles

	As-Received	After maintenance based on Check Engine Light	After maintenance based on Idle Test
HC	0.36	0.34	0.34
CO	4.86	3.97	4.10
NOx	0.73	0.72	0.73

Table 2
Reductions in Fleet Average Emission Levels
(grams/mile)

	After maintenance based on Check Engine Light	Idle Test
HC	.02	.02
CO	.89	.76
NOx	.01	.00

Examination of the test results show essentially no difference in fleet average emission levels for HC and NOx after maintenance based on vehicles identified by either the Check Engine Light or the idle test approach. "After maintenance" emission levels are basically the same as "as-received" emission levels. Some fleet average CO emission reductions are shown, but the results favor neither the CEL nor the idle test approach. These results suggest that the value derived from an I/M program using either approach is therefore questionable .

Advantages and Limitations - An on-board diagnostic inspection approach to I/M has a number of advantages over the traditional short test approach. A few are listed below.

1) No test equipment required.
2) No standards to establish.
3) No specific inspector training.
4) Owner can perform inspection.
5) Repair diagnoses are simplified and problems are identified rather than trying to reduce idle HC and CO values.
6) Some NOx problems are identified.
7) Coincides with manufacturer's recommended procedures.

With the on-board diagnostic approach to I/M, the need for an exhaust gas analyzer and to establish short test standards is eliminated. Inspector training is minimal. Owners know at all times whether or not the CCC system is functioning properly and if their vehicles will pass the annual inspection. The system provides a positive indication that something is wrong with an emission circuit as opposed to a vehicle that fails a short test where the repair process begins with making a determination if something is wrong. Another significant advantage is that the inspection and repair procedures coincide with the manufacturer's recommended maintenance and repair procedures which were developed to yield optimum vehicle performance while complying with emission standards.

There are also a number of limitations that should be mentioned. The current on-board diagnostics do not detect all the problems which could occur with a vehicle that could affect emissions. The diagnostics were designed to identify specific malfunctions in the CCC system. As a result, a fouled spark plug would not be detected by the on-board diagnostics. Another limitation to this type of inspection is the lack of a quantitative measurement as the tailpipe short test provides. In addition, the approach is also obviously limited to vehicles with on-board diagnostics. But, limitations are not unique to the on-board diagnostic approach. For example, results of an idle test are dependent on various factors such as instrument calibration, integrity (leak-proof) of the exhaust system, and the state of warm-up which affects choke operation and catalytic converter efficiency. An idle test can only identify warmed-up idle problems, and it provides minimal diagnostic information. The above factors obviously can have a significant effect on the measurement of tailpipe emissions during an idle short test.

Potential Implementation Methods

The feasibility of using on-board diagnostics for I/M has been demonstrated. Possible implementation methods will now be considered for both current and future vehicle populations.

Currently, only a few vehicles in addition to the 1981 and later model year GM cars have on-board diagnostics. At this time, it would seem impractical to implement a state inspection program that only performed an on-board diagnostic inspection. However, on 1981 and later model year GM cars, an I/M station could perform a visual inspection of the Check Engine Light in place of an existing short test inspection. The I/M station would simply verify that the diagnostic system is working by checking if the Check Engine Light is "on" with the ignition "on", but the engine not running. If the Check Engine Light then goes out after the engine is started, no permanent problem currently exists with the CCC system circuits. (Intermittent problems might be detected by checking for stored codes in the memory of the ECM.)

General Motors plans to continue to incorporate emission control diagnostics in our designs. Other manufacturers may also use diagnostics in their designs, either on-board or through a repair station diagnostic device. In the future if a larger percentage of the in-use vehicles are equipped with diagnostic capabilities, it is conceivable that an I/M program may solely use a diagnostic inspection procedure.

Summary and Conclusions

General Motors' Computer Command Control system with on-board diagnostics is new. It's different! The on-board diagnostics with the Check Engine Light was designed for the purpose of informing the vehicle operator of a potential problem with the emission control system and to facilitate repair. However, the on-board diagnostics enables I/M programs to utilize this feature as an emission control system inspection technique.

Based on an analysis of EPA in-use vehicle emission test results, it was demonstrated that fleetwide emission reductions would result from an inspection program which utilized the on-board diagnostics for the inspection. The use of on-board diagnostics for I/M is feasible and in the future, as more systems are represented in the in-use vehicle population, it may be very practical. However, more significant is the fact that vehicles with the Check Engine Light and on-board diagnostics are continually under scrutiny by the owners/operators of the vehicles and undergoing continual ongoing I/M which is undoubtably more effective than any annual inspection.

COMPUTER COMMAND CONTROL

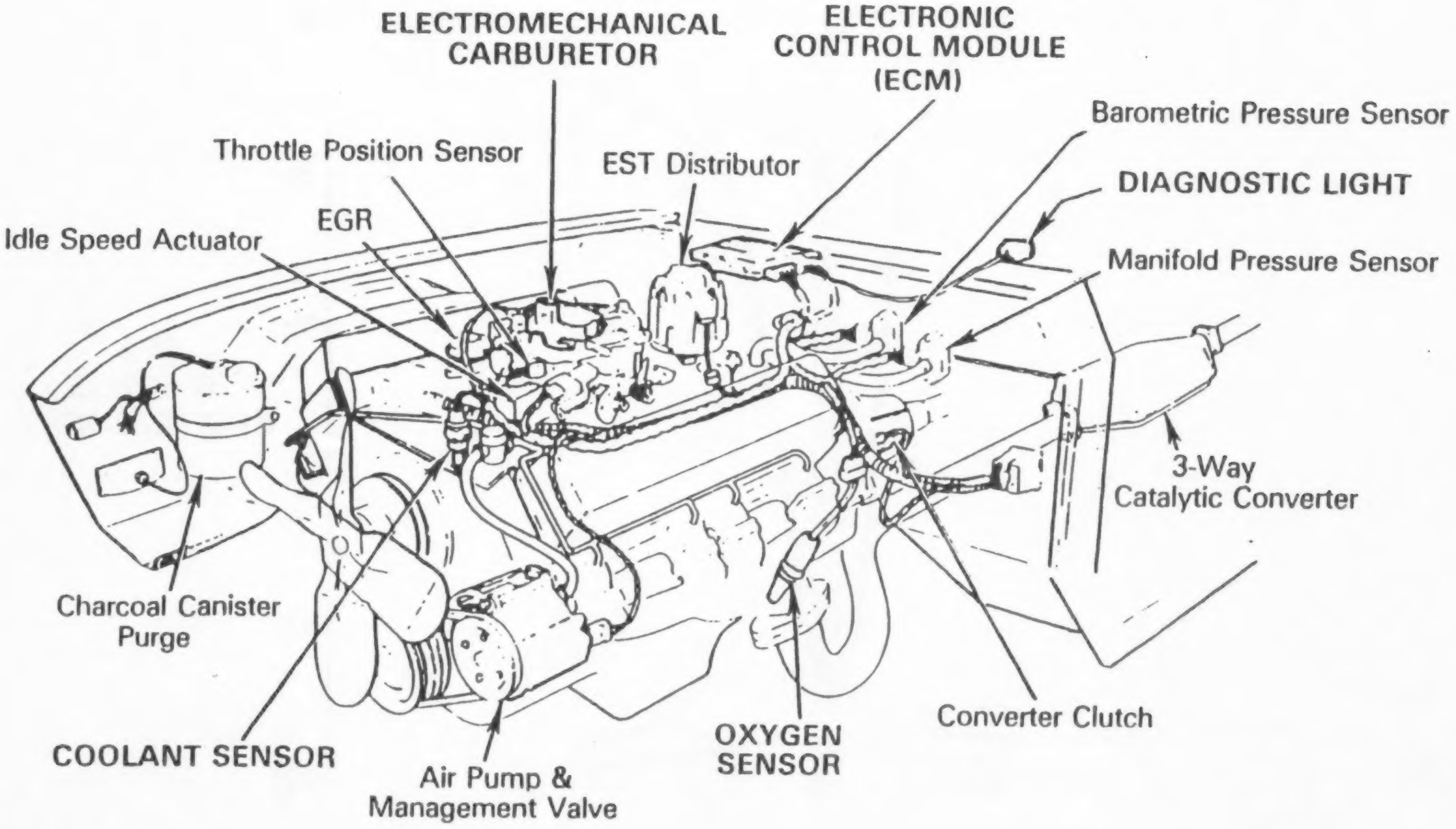
ELECTROMECHANICAL CARBURETOR
ELECTRONIC CONTROL MODULE (ECM)
Barometric Pressure Sensor
Throttle Position Sensor
EST Distributor
DIAGNOSTIC LIGHT
EGR
Idle Speed Actuator
Manifold Pressure Sensor
3-Way Catalytic Converter
Charcoal Canister Purge
COOLANT SENSOR
Air Pump & Management Valve
OXYGEN SENSOR
Converter Clutch

FIGURE 1

PRINCIPLE OF OPERATION 3-WAY CATALYST

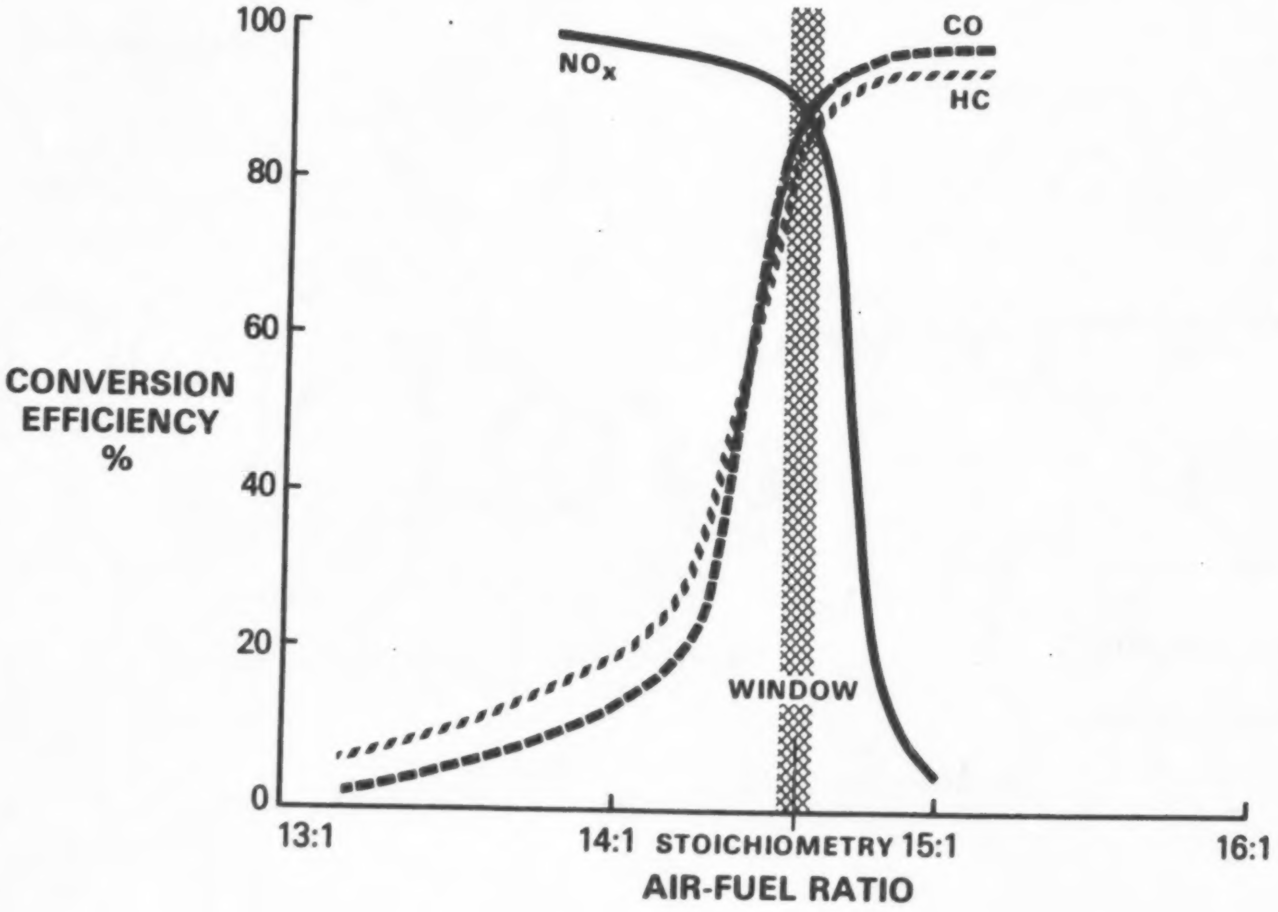

FIGURE 2

CHECK ENGINE LIGHT

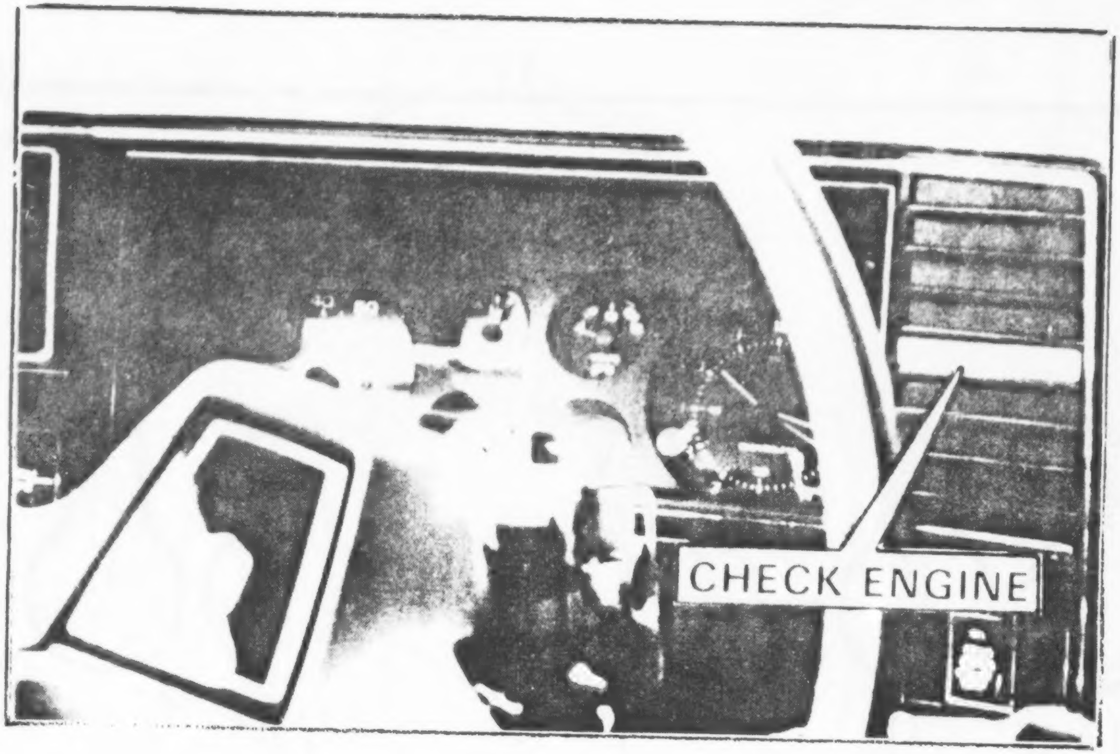
CHECK ENGINE

FIGURE 3

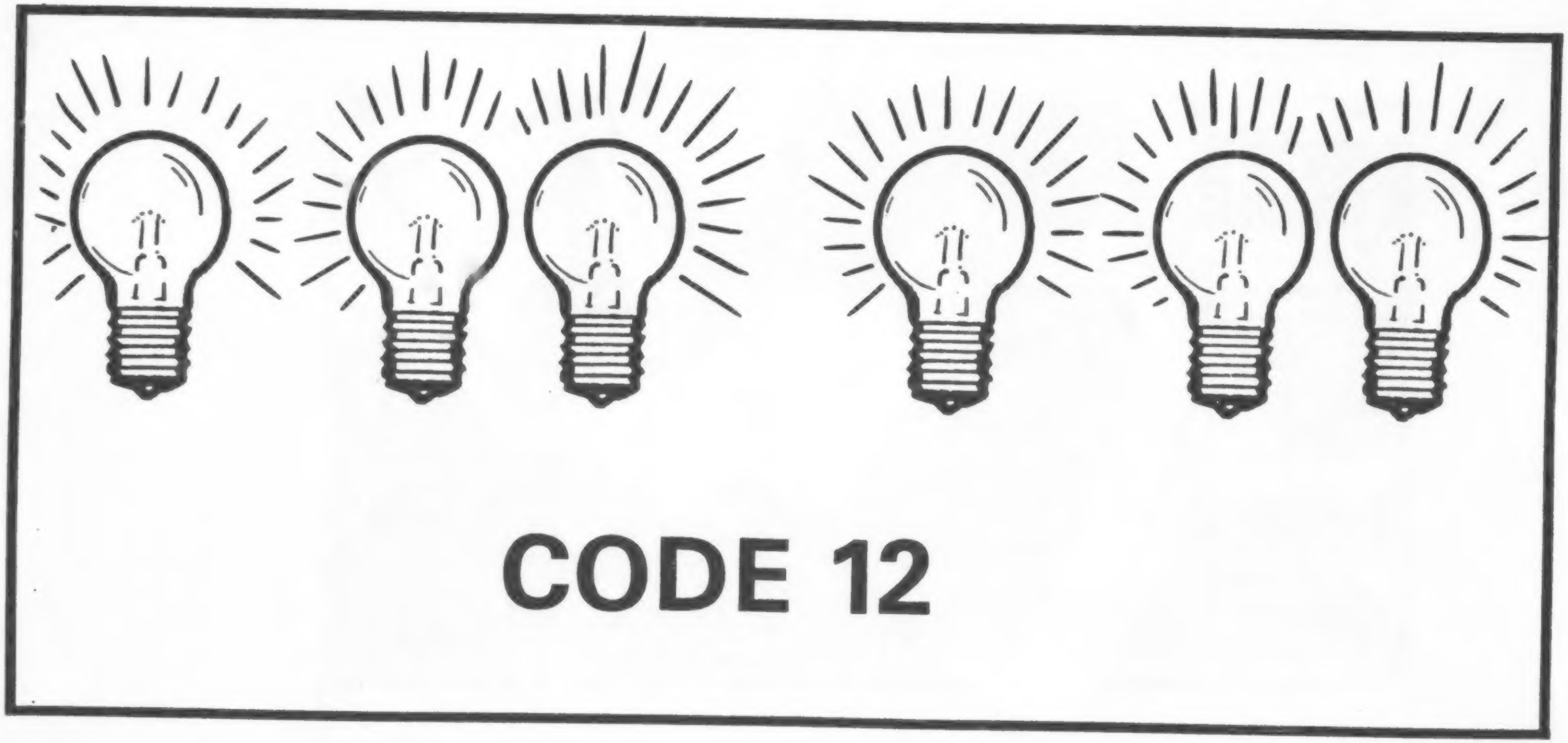

FIGURE 4.

FIGURE 5

Typical Self-Diagnostic Flashing Codes

MALFUNCTION DESCRIPTION	DIAGNOSTIC CODE
Dist (RPM)	12
O_2 Sensor	13
Coolant Temp Sensor	14
Coolant Temp Sensor	15
Throttle Pos. Sensor	21
Throttle Pos. Sensor	22
Carb Solenoid	23
Veh. Speed Sensor	24
Baro Sensor	32
Press Sensor (MAP)	33
Press Sensor (MAP or VAC)	34
ISC	35

MALFUNCTION DESCRIPTION	DIAGNOSTIC CODE
Dist Ref. Pulses	41
HEI Module	42
ESC	43
Lean Exhaust	44
Rich Exhaust	45
Prom Error	51
Carb Solenoid Driver Error	54
A/D Error	55

Field Service Support Program

- 1981 GM CCC Vehicles
- 27 Dealerships
- More than 2500 Service Incidents

Service Incident Resulting from

Check Engine Light ONLY	42%
Check Engine Light AND Driveability Complaint	9%
Other Owner Complaints	49%
	100%

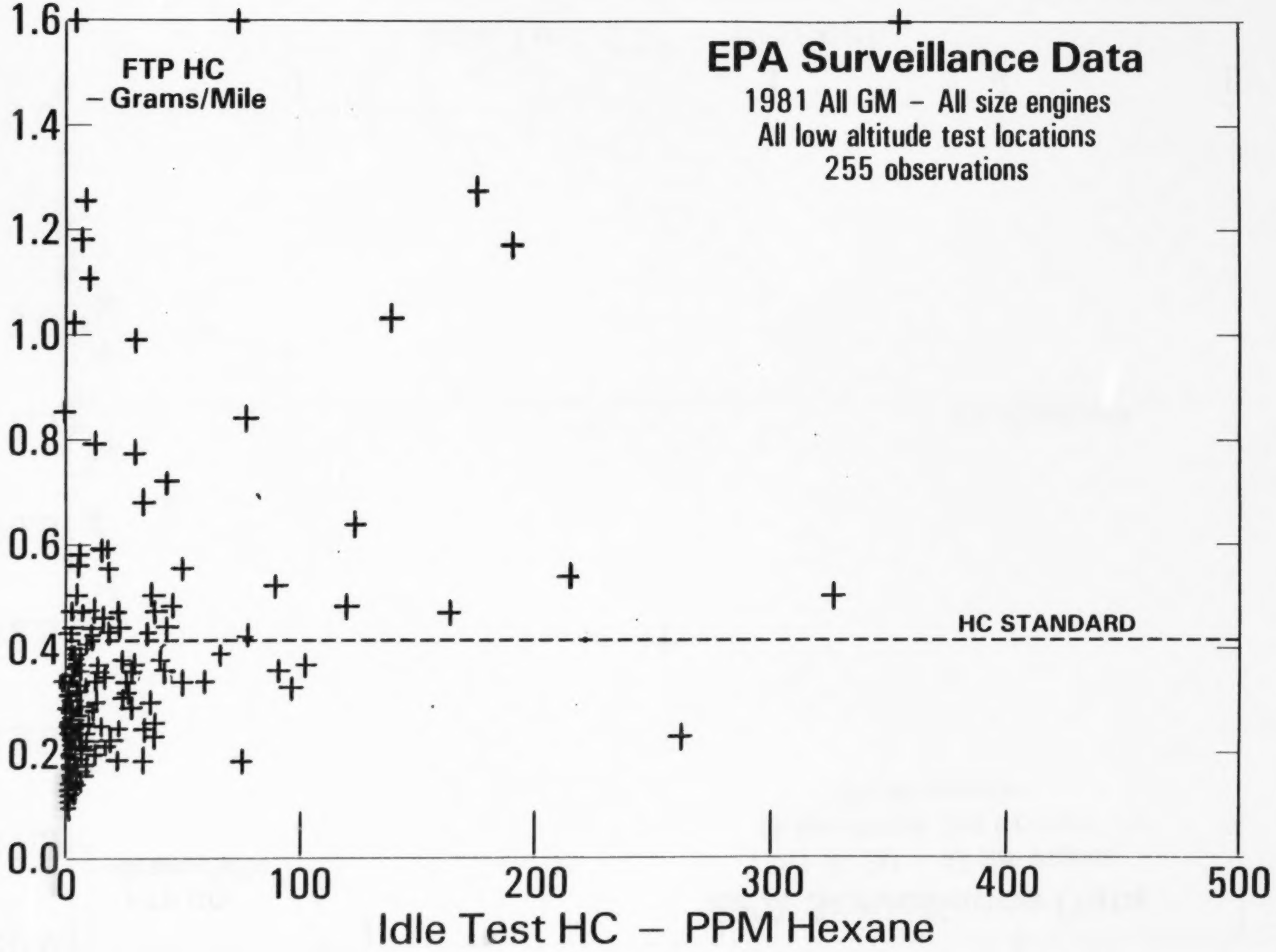
EPA Surveillance Data
1981 All GM – All size engines
All low altitude test locations
255 observations
FTP HC
– Grams/Mile
HC STANDARD
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
Idle Test HC – PPM Hexane

FIGURE 7

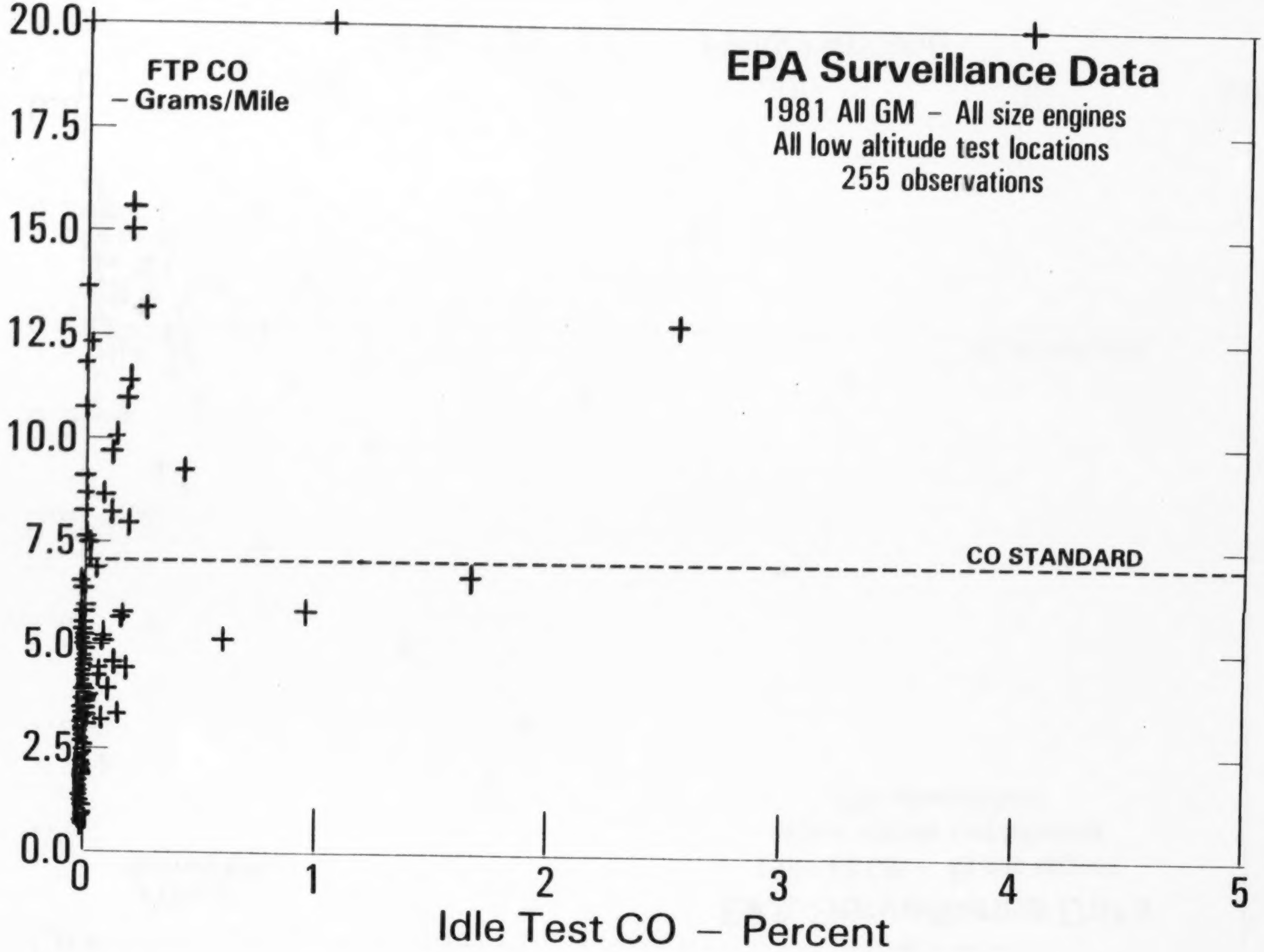
EPA Surveillance Data
1981 All GM – All size engines
All low altitude test locations
255 observations
FTP CO – Grams/Mile
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
CO STANDARD
0
1
2
3
4
5
Idle Test CO – Percent

FIGURE 8

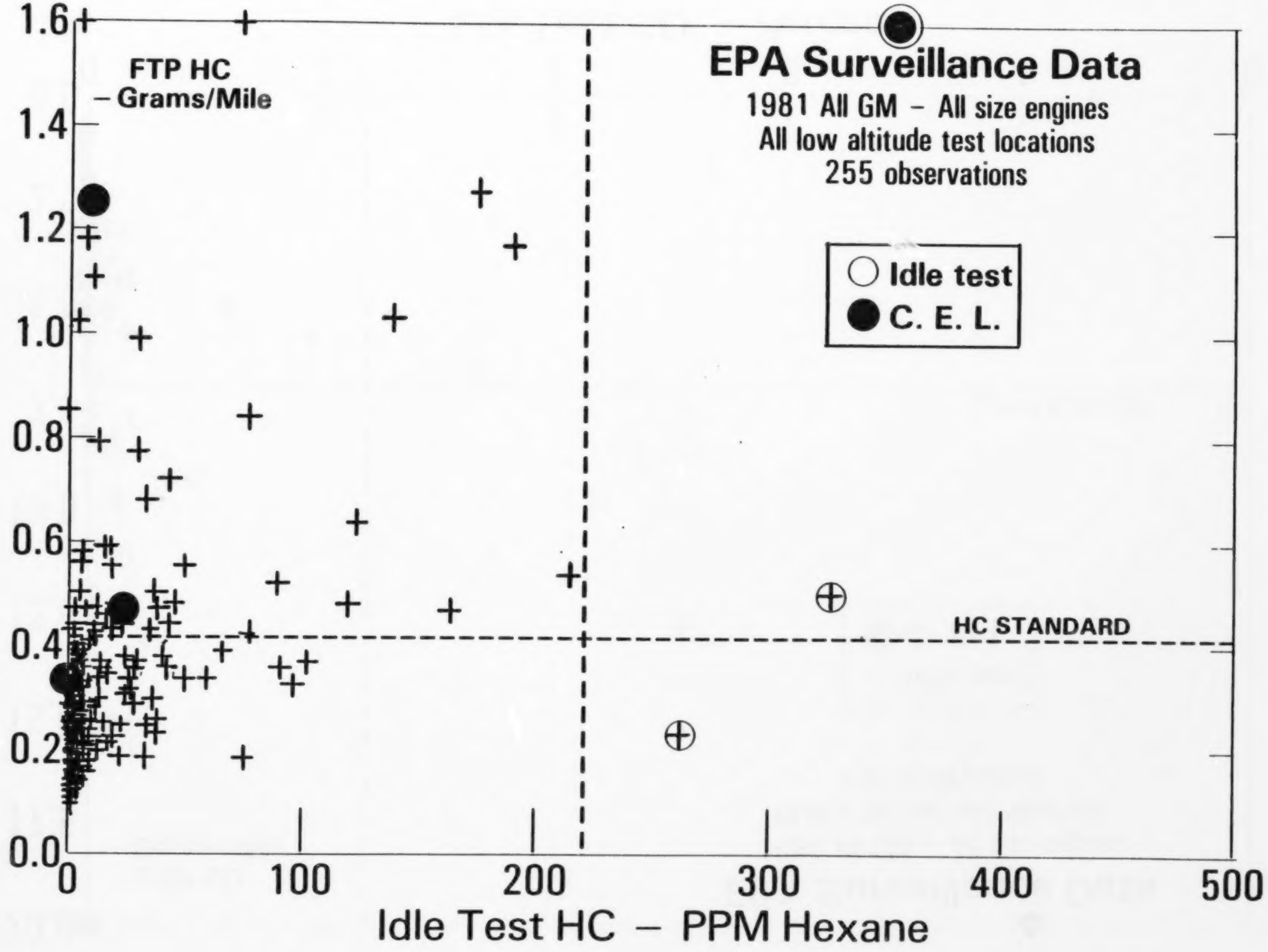
EPA Surveillance Data
1981 All GM – All size engines
All low altitude test locations
255 observations
○ Idle test
● C. E. L.
FTP HC – Grams/Mile
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
HC STANDARD
0
100
200
300
400
500
Idle Test HC – PPM Hexane

FIGURE 9

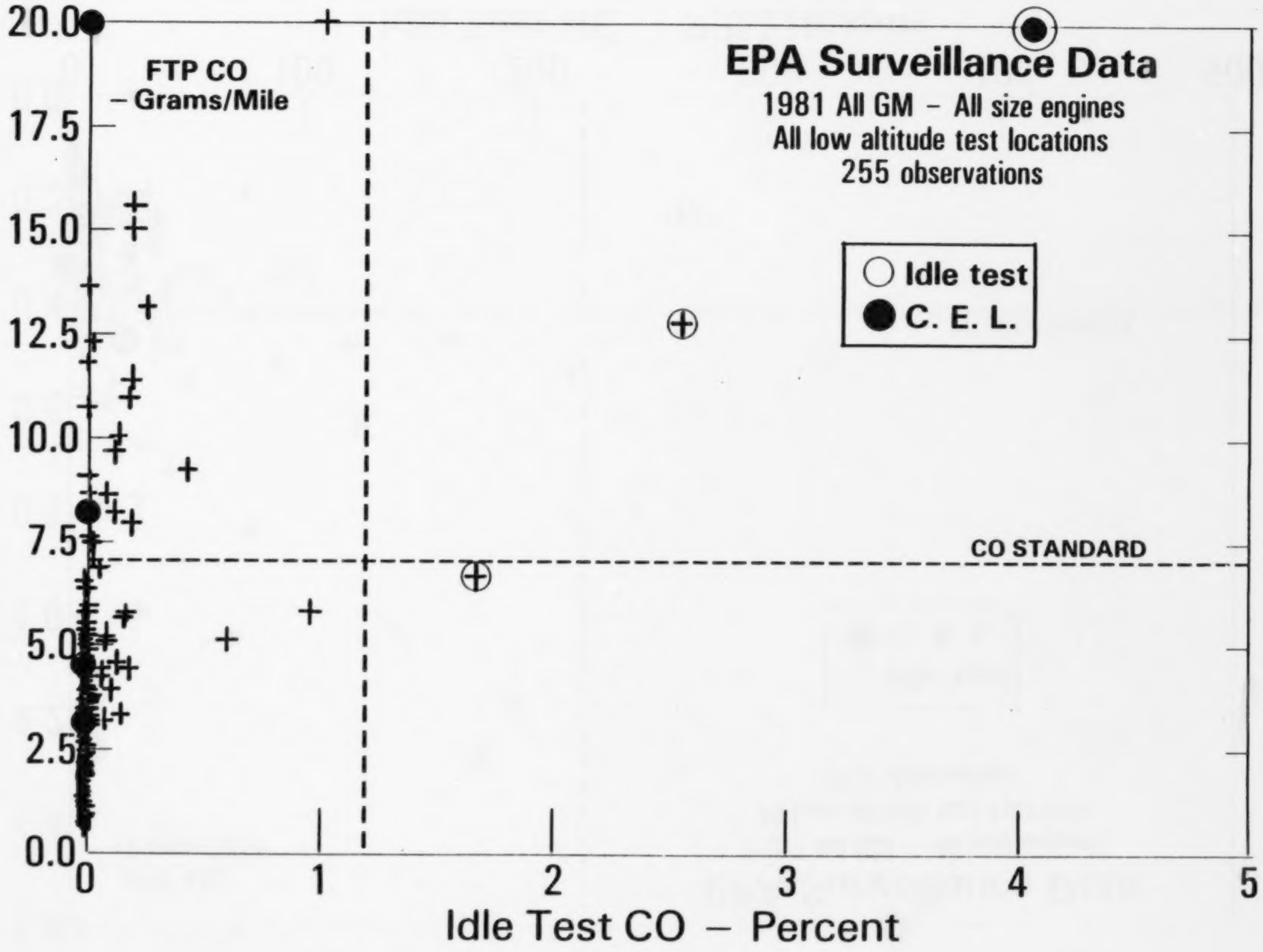
EPA Surveillance Data
1981 All GM – All size engines
All low altitude test locations
255 observations
○ Idle test
● C. E. L.
FTP CO
– Grams/Mile
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
CO STANDARD
0
1
2
3
4
5
Idle Test CO – Percent

FIGURE 10

SUMMARY

THE CLEAN AIR ACT DEBATES:

The Aftermarket is Throwing Out the Baby With the Bathwater

By

Benjamin R. Jackson

Aftermarket parts and service industries associations have been concerned for years about two (2) mandated government programs emanating from the Clean Air Act. One is the warranty program (the bathwater) requiring auto manufacturers to provide emissions control warranties; the other is the inspection/maintenance program (the baby) requiring consumers to have periodic tune-ups.

Prior to commencement of the current debate over amendment of the Clean Air Act, the aftermarket consistently took the position that the warranties should be restricted to two (2) years or less (instead of the five (5) years originally prescribed in the Act) and to emission control parts (instead of any part that could affect emissions). The concern was that the warranty would cause consumers to take their cars back to dealers instead of independent repair shops. In 1977, aftermarket lobbyists obtained an amendment to the Act to cut back part of the warranty program. This time around the lobbyists went after the remainder of the warranty program. All this activity is premised on concern over prospective effects, for no one has measured (and this repair shop operator has not seen) any of the dread effects of the warranties yet. Indeed the experts that forecast for growth in the aftermarket parts and service industry ignore any affect of the Clean Air Act warranties.

Also, prior to commencement of the current debate, the aftermarket supported the requirement for I/M programs -- for obvious reasons. I/M programs would increase the auto repair business. The auto companies, on the other hand, have long resisted I/M, since I/M would shift part of the burden of lowering auto emissions from the auto companies to the consumer by requiring the consumer to have his car maintained. But a couple of plausible reasons why auto companies oppose I/M are: (1) their potential emissions warranty liability and (2) their potentially increased recall liability as the government's surveillance capability increases through the I/M program. This time around the aftermarket lobbyists abandoned their support for I/M because the auto makers (and others) do not like it. To be fair, one should acknowledge a legislative strategy on the part of the lobbyists that would have the proposed warranty amendments be endorsed by the auto industry and carried through Congress on the auto company bandwagon. Regardless of whether that strategy is a good one, the inherent choice of warranty amendments over I/M is a bad one.

The aftermarket stands more to gain from I/M than it does from elimination of the remaining warranties.

The business to be lost by the independent repair shops is entirely speculative. Auto dealerships with their high costs and long waiting lines for service of new (two years or younger) cars are pretty effective at driving consumers to independent repair shops for service. It is not likely that consumers who otherwise would buy a tune-up for half the price and a fraction of the time from an independent shop will turn to auto dealers when the frequency of tune-ups is required to increase under an I/M program.

On the other hand, the business to be gained from the increase in frequency of tune-ups under an annual I/M program is entirely certain. Any self-respecting repair shop can guarantee that his tune-up will pass the I/M test. And, if he discovers a defective part of significant costs that is still under warranty, he can send the consumer to the auto dealers. It will not happen often enough to worry about. He will probably have already sold the consumer a tune-up, and he will surely get the customer back for the next one.

The lobbyists have made a poor choice. The baby (I/M) has been thrown out with the bathwater (warranties). Another strategy is available that will offer consumer protection and at the same time avoid anti-competitive effects while supporting I/M.

NINTH ANNUAL NORTH AMERICAN MOTOR VEHICLE EMISSIONS CONTROL CONFERENCE

RAMADA VALLEY HO RESORT
SCOTTSDALE, ARIZONA
MAY 4 - 7, 1982

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